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## **CHEMISTRY FOR NURSES**



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## **CHEMISTRY FOR NURSES**



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# CHEMISTRY FOR NURSES

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## PREFACE

THE teaching of chemistry to nurses is a new thing, but the development of medicine has made it inevitable. Some knowledge of the fundamental conceptions of chemistry is as indispensable as anatomy in the modern treatment of disease. Indeed it puzzles one to understand how, in the past, without chemical instruction, nurses have made any sense at all of much that was taught them in materia medica, physiology, and diet cooking. How rapidly this opinion is gaining adherents is shown by the responses to an inquiry sent by the author to the examining boards of thirty-two states of the Union; in twenty-two states, the answers showed, questions in chemistry formed part of the examination for registered nurses.

This book has been written therefore in response to what the author believes to be a real need. There is no simple yet modern textbook on this subject. In the past nurses anxious for information were compelled to refer either to textbooks written for medical students and much too difficult for the average nurse, or to school textbooks,

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written from a different point of view and paying no attention at all to many subjects of peculiar importance to nurses.

Chemistry to the nurse is an accessory study,—an aid to the understanding of other studies of undoubtedly greater practical importance. For this reason the present book is to be used by the nurse not as a catalogue of facts to be learned outright, but as a reasoned explanation of things which otherwise would remain obscure. The author therefore has avoided all technicalities and has attempted to make the text as readable and entertaining as possible. The subject of chemistry with its innumerable and important bearings on everyday life usually fascinates every beginner who overcomes the initial fear of its technical difficulty.

This book is the development of a short course of lectures given to the undergraduate nurses of the Mount Sinai Hospital at various times in the past two years. The experiments described have all been demonstrated to classes of nurses and can easily be performed with the simplest equipment. It is suggested that teachers perform these experiments before their classes.

The author wishes to thank several of his friends for their kindly criticism: Dr. Samuel Bookman,

Chemist to Mount Sinai Hospital; Miss George, Dietitian to Mount Sinai Hospital; Dr. A. S. Blumgarten, author of "Materia Medica for Nurses"; and particularly Mr. Joseph Loew of the De Witt Clinton High School, New York.



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# CHEMISTRY FOR NURSES

## CHAPTER I

### ELEMENTS AND COMPOUNDS

**Two Kinds of Changes in Matter.** — Since the earliest times men have been studying the different kinds of matter or substances of which the world is composed, and have noticed that these substances frequently undergo *changes* in appearance and form. Gradually they have come to see that these changes are of two different kinds: the one kind is more or less *transient*. Thus the change from solid to liquid, as in the melting of ice, or from liquid to gas, as in the boiling of water, the glowing of metal when it is heated, are temporary changes. The water can freeze again, the steam can condense, the metal can cool. Changes of this kind in matter are known as *physical changes*, and their study constitutes the science of physics.

**Chemical Changes.** — But substances also undergo another kind of change much more *permanent* in

nature. Wood may burn in the flame until nothing is left but ashes, or metals rust and lose their original appearance entirely. Such deep-going changes in matter are known as *chemical changes*, and their study is the science of chemistry.

**Elements.** — Chemical changes often result in *breaking up* one substance into several products. Thus, for instance, when a piece of wood burns there are fumes given off; at a certain stage there is a black residue composed of carbon (charcoal); and if the burning is continued for a long while, white ashes. The products of such chemical changes can often be further decomposed into still other substances.<sup>1</sup> When this process is continued, certain forms of matter are finally obtained which cannot by any means whatever be resolved into other substances. These are called elementary substances or *chemical elements*.

**Compounds.** — By studying all sorts of substances in this way the chemists have discovered that all the matter in the universe is composed of about

<sup>1</sup> When the combined weights of all the substances produced by such decompositions are compared with the weight of the original substance, they are found to be exactly equal. Matter has been changed into different states, but no matter has been made or destroyed. This is the law of the indestructibility of matter.

eighty of these elements; everything from a microbe to a star is composed of these same eighty elements in different forms and combinations.

It took centuries to find this out because it is not easy to discover what elements are present in a substance. The reason for this difficulty is that when different elements combine to form a new substance they lose their properties entirely. *The properties of the compound are nothing like the properties of the elements themselves.* Who would think from the properties of water, for instance, that it was composed of two light gases which explode when they are mixed together and ignited? Or, consider common salt, sodium chloride. It is a combination of two elements, — sodium and chlorine. Chlorine is a yellow poisonous vapor. Sodium is a soft metal, very hard to keep in its natural state because it corrodes and combines with almost everything it touches. These two violent things with their peculiar properties combine and the result is our harmless table salt.

**Difference between Mixtures and Compounds.** — But it must not be supposed that just because elements are mixed together the result is necessarily a new compound. Substances may be simply *mixed together* very intimately without undergoing any combination (in such a way as to form new



properties) at all. If you mix particles of carbon (lamp black) and of sulphur, the mixture has no new properties and the two kinds of particles can be recognized separately under a microscope. But if, instead of this, sulphur in the form of vapor is made to pass over the red-hot charcoal, an entirely new substance (carbon disulphide) is formed. It is a volatile and strong-smelling liquid which is of enormous importance in the manufacture of rubber and various perfumes. This, then, is the difference between a mixture and a compound: in a mixture the substances are present in their original form and are easily separated; in a compound the elements have undergone a peculiar change by which they not only acquire entirely new properties, but are firmly united so that it takes some powerful force like great heat or a strong electric current or powerful chemical action to separate them.

All sorts of elements combine with each other and thus there are thousands of compounds: the number of possible compounds is almost infinite.

**Constant Composition of Compounds.** — In spite of the great number of compounds formed by the union of different elements *each compound always has precisely the same composition*, no matter under what conditions you find it. If you take specimens

of water from a dozen different sources and separate the elements in them, you will always find exactly the same proportion of hydrogen and oxygen. You never find more oxygen in one specimen of water than in another. This fact, that the elements in any chemical compound are always present in precisely the same proportions, is another one of the things that distinguish compounds from mixtures. It is obvious, of course, that in a mixture any amount of the one or the other ingredient may be present. There is a fundamental reason for this constancy of composition of compounds. This reason will be made clear in the next chapter.

**How can Different Compounds be composed of the Same Elements?** — But the same elements may combine in several different proportions to form several different compounds. For instance, take another compound of hydrogen and oxygen, namely, peroxide of hydrogen. It is a combination of exactly the same elements as water, but the elements are combined in a different ratio. The amount of oxygen present in any given amount of peroxide of hydrogen is twice as large as in the same amount of water. On this account peroxide of hydrogen is entirely different in its properties from water. It attacks and decomposes organic things such as blood or bacteria.

But peroxide of hydrogen in its turn does not vary. The proportions of hydrogen and oxygen obtained from different specimens of it are always the same.

There are two general methods of studying compounds, — *analysis* and *synthesis*. Analysis means decomposition of a compound into the elements which compose it: synthesis means combining different elements to form new compounds.

**The Most Important Elements.** — Below is a partial list of elements. The list includes all the elements which are met in everyday life and which play an important part in medicine or nursing. Many of them, such as carbon and sulphur and the metals, are already familiar in their natural state. The student will easily be able to think of compounds of most of the others. A short description of most of these is found in the appendix to Chapter I.

|               |                |
|---------------|----------------|
| 1 — Aluminium | 11 — Hydrogen  |
| 2 — Arsenic   | 12 — Iodine    |
| 3 — Bismuth   | 13 — Iron      |
| 4 — Boron     | 14 — Lead      |
| 5 — Bromine   | 15 — Lithium   |
| 6 — Calcium   | 16 — Magnesium |
| 7 — Carbon    | 17 — Mercury   |
| 8 — Chlorine  | 18 — Nickel    |
| 9 — Copper    | 19 — Nitrogen  |
| 10 — Gold     | 20 — Oxygen    |

|                 |                |
|-----------------|----------------|
| 21 — Phosphorus | 27 — Sodium    |
| 22 — Platinum   | 28 — Strontium |
| 23 — Potassium  | 29 — Sulphur   |
| 24 — Radium     | 30 — Tin       |
| 25 — Silicon    | 31 — Zinc      |
| 26 — Silver     |                |

## IMPORTANT ELEMENTS AND COMPOUNDS

1. **Aluminium** — a light, white metal, which, combined with other elements in the form of clay or of various minerals, forms a large part of the earth's crust. Its compound, *aluminium acetate*, is used in surgical dressings.
2. **Arsenic** — a metal. Its compounds are exceedingly poisonous, and some are used as drugs.
3. **Bismuth** — a heavy, lustrous metal whose compounds are mostly insoluble (do not dissolve in water) and are used in medicine. On account of being insoluble, bismuth compounds when given as medicines are found in the stools again. They undergo a chemical change which gives the black color to bismuth stools.
4. **Boron** — mentioned because of its compounds, *boric acid* and *borax*.
5. **Bromine** — a heavy, very poisonous, and irritating brown liquid, the compounds of which, known as *bromides*, are of great use in medicine.
6. **Calcium** — a yellow metal which when heated takes fire and burns. One of its compounds (calcium carbonate) forms *marble* and *limestone*; another (calcium phosphate) is the chief constituent of

*bones.* We could not live without calcium and it is present in all animals and vegetables.

7. **Carbon** — occurs as diamond, graphite, charcoal. Its compounds are very numerous and all living things are composed chiefly of them.
8. **Chlorine** — a poisonous, greenish gas, similar in many ways to bromine and iodine. Its compounds, such as *hydrochloric acid*, *sodium chloride*, potassium chlorate, are of great importance in physiology and medicine.
9. **Copper** — a common metal, one of whose compounds, copper sulphate, is a valuable cauterizing agent.
10. **Gold** — a metal which has very few compounds. This is what makes it a “precious” metal. It does not combine readily with other elements, and therefore does not corrode or rust, but remains unchanged for centuries.
11. **Hydrogen** — a non-poisonous gas, the lightest substance known, and one of the most abundant and important of all the elements, — present in all living matter. *Not* present as such in the air.
12. **Iodine** — shining black crystals, which, dissolved in alcohol, are the familiar tincture of iodine. Traces of it are found in the thyroid gland, and it is important for health, though exactly why is unknown. Some of its compounds (*iodides*) are valuable drugs.
13. **Iron** — important not only as a metal, but also in its compounds, some of which are valuable drugs, and one of which, *hæmoglobin*, is the red coloring matter of our blood and is essential for respiration.

14. **Lead** — is a heavy metal; it can easily be fluidified by heat. Its soluble compounds are poisonous. Some of them are used in medicine (*lead acetate*).
15. **Lithium** — is a light metal, some of whose compounds are used in medicine.
16. **Magnesium** — a silvery white metal which burns brilliantly in the air. (The *flash light* of photographers is powdered magnesium.) Some of its compounds, such as *magnesium sulphate*, *citrate*, *carbonate*, and *hydroxide* (milk of magnesia), are important drugs.
17. **Mercury** — a heavy fluid metal whose compounds are familiar and important drugs (*calomel*, *bichloride of mercury*).
18. **Nickel** — a metal.
19. **Nitrogen** — an inert (not chemically active) gas which forms about  $\frac{4}{5}$  of the air. Its compounds, *ammonia*, *nitrous oxide* or *laughing gas*, *nitric acid*, *niter* or *saltpeter* (potassium nitrate), are used in medicine. In the form of *proteid* it is not only an essential food, but is present in every living cell.
20. **Oxygen** — is a colorless, odorless gas which forms about  $\frac{1}{5}$  of the air and  $\frac{1}{2}$  of the earth. It can combine with almost every other element, and the process of its combination is known as oxidation or combustion. It is essential to respiration and is present in every living cell. Of its innumerable compounds, water is the most important. Oxygen gas can be readily recognized by the fact that glowing substances are set on fire or burning substances burn much more brightly when introduced into it.

21. **Phosphorus** — is a waxlike solid which shines in the dark and readily catches fire. It is used in making matches and is very poisonous. Some of its compounds, such as *sodium phosphate*, are used as drugs. Another of its compounds, *calcium phosphate*, forms about 60 % of *bone*, and is also present in all fertile *soils*, — is, in fact, essential to the growth of plants. Other important compounds are present in the blood, in the brain, and in the urine.
22. **Platinum** — a metal used in jewelry; does not enter into the body. It is a “precious” metal for the same reason as gold.
23. **Potassium** — a shining white metal which readily forms compounds with a great many other elements. When thrown into water it unites with it so actively as to take fire. It has a great number of important compounds, such as *caustic potash* (potassium hydrate), *potassium chlorate*, *potassium iodide*, *potassium bromide*, *potassium nitrate*, and many others.
24. **Radium** — a peculiar metal which gives off very penetrating rays like X rays. It was recently discovered by Mme. Curie. It is used in the treatment of certain skin diseases and cancers.
25. **Silicon** — is not of much importance to our bodies, but it is, nevertheless, next to oxygen the most abundant element. It forms a large part of *rock*, [*sand*, *clay*, and *soil*]. *Glassware* contains much silicon, as do a great many other things that we handle; it is contained in the many forms of stone and crockery dishware. It is very insoluble.

26. **Silver** — a metal, some of whose compounds such as silver nitrate, argyrol, protargol, are used in medicine.
27. **Sodium** — a very widespread element, the sister metal of potassium, and with very similar properties. Some of its compounds, as *sodium chloride*, *carbonate*, *bicarbonate*, are important constituents of the blood.
28. **Strontium** — is somewhat similar to sodium and potassium. Some of its compounds, such as strontium bromide, are used as drugs.
29. **Sulphur** — is a yellow, inflammable solid used directly as a drug. Its compounds, such as *sulphuric acid*, *magnesium sulphate*, etc., are important in medicine. It is found in many parts of the body, such as skin and hair.
30. **Tin** — a metal.
31. **Zinc** — a metal some of whose insoluble compounds, such as zinc oxide, are used in medicine for their soothing properties. Its soluble compounds, like zinc sulphate and zinc sulphocarbolate, are poisonous and are used as disinfectants and cauterizing agents.



## CHAPTER II

### ATOMS AND MOLECULES

**The Use of Hypotheses in Science.** — In order to explain the phenomena of nature, scientists often use *hypotheses*, or working theories. These are suppositions which explain the facts, but which for the time being cannot be proved completely. One of the most useful and important of these hypotheses is the *atomic theory*, — the idea that all substances are composed of extremely minute particles. Although nobody has ever seen one of these particles, the theory is so useful and explains so much that the whole development of modern chemistry has been built up on it.

**Molecules.** — Suppose that we commenced to divide any substance, say a drop of water, into smaller and smaller particles, and suppose that we had instruments fine enough so that we could continue this division as long as we wanted to, we would finally reach a particle so small that if it could be further divided, it would no longer be water. These

*particles* of which water is believed to be formed are called *molecules*.

If the molecule of water were broken up into its constituents, hydrogen and oxygen, it would no longer have the properties of water. Hence a *molecule* is defined as the *smallest weight of any kind of matter in which the original properties of the matter are retained*.

**Atoms.** — But suppose that instead of starting with a compound we were to start with an element itself. Here, too, an overwhelming array of evidence has led scientists to make the hypothesis that ultimately particles would be reached which could not be further subdivided. These particles are known as *atoms*.<sup>1</sup>

**Molecules Composed of Atoms.** — In the first chapter it was stated that the composition of any compound is absolutely constant; when any compound is analyzed into its elements we always get exactly the same amount of each of the elements from any given amount of the compound. We see now why this is so. *Each molecule of a compound*

<sup>1</sup> Recent discoveries in connection with radium and X rays have brought to our knowledge particles far smaller even than atoms, — particles out of which probably atoms themselves are made.

*has the same number of atoms as every other molecule of the compound.* Every molecule of water has one atom of oxygen and two atoms of hydrogen. Therefore, water, no matter where or how obtained, always has constant amounts of oxygen and hydrogen.

**Size of Molecules.** — The absolute size of atoms and molecules is not known. All atoms and even the largest molecules, those known to contain thousands of atoms, are far too small to be seen through the most powerful microscope. It will give you some idea of their size to know that it has been calculated that if a single drop of water were magnified to the size of the earth, the molecules would be something like the size of baseballs.

**Weight of Atoms.** — The atoms of the different elements have different weights; the atoms of the same elements are all alike. Though their absolute weights are not known, the relative weights of all the atoms are known with great accuracy. Hydrogen is the lightest and is taken as the standard, while the atom of radium, one of the heaviest, weighs two hundred and twenty-five times as much as the atom of hydrogen.

## PHYSICAL STATE OF MATTER

**Changes in Physical State of Molecules.** — A substance remains unchanged no matter what vicissitudes it goes through as long as the atoms in its molecules remain together. The molecule of water is the same whether in steam, or water, or ice. But the positions and motions of the molecules may vary. In steam and in all gases the molecules are separated by space and vibrate to and fro. This causes the pressure of gas on the containing wall (for instance, the pressure of the gas in a balloon). In fluids the molecules are packed much more closely together, but they still move to and fro. In solids their relative positions are fixed. The physical state of a substance, whether it is solid, fluid, or gas, depends on temperature and pressure, and it is possible to obtain most substances in any one of these three forms.

Thus we have reached a different idea of chemical and physical changes from that given in the first chapter. *Chemical changes are those in which the atoms in the molecule are changed. Physical changes are changes in which the molecules retain all their atoms intact.* This is the reason that chemical changes are generally more permanent and deep-going than physical changes.

Many physical processes, such as dissolving, boiling, distilling, crystallizing, are made use of in chemical operations.

**Solution.** — When sugar or salt is put into water it disappears (dissolves), but its presence in the water can be recognized by the taste. If more salt or sugar is gradually added, a limit is finally reached, at which no more can be dissolved. The solution is *saturated*.<sup>1</sup> If now the water is warmed, it will dissolve some more sugar or salt, for the *solubility of most solid substances increases as the temperature rises*. If the solution is saturated while very hot and then allowed very slowly to cool, some of the sugar or salt will appear again in the form of crystals.

**Crystallization.** — Likewise, if some of the water evaporates from a saturated solution, crystals form. Crystallization is one of the methods used in chemistry and in manufacturing to obtain substances in a pure state. For a crystal contains not a mixture of two substances, but only one substance.

**The Right Solvent must be Chosen.** — Substances may dissolve not only in water, but in other fluids. Moreover, the solubility of different substances in different fluids varies greatly. Thus water will dis-

<sup>1</sup> See Chapter on Solutions in Blumgarten's "Materia Medica for Nurses."

solve large amounts of salt, but will not dissolve fat at all. Ether, on the other hand, dissolves fat readily, but not salt.

**Solubility of Gases.** — A fluid may dissolve not only solids, but also various fluids and gases. For instance, ether or chloroform will dissolve to some extent in water. A familiar example of a dissolved gas is carbonated water (carbonic acid gas dissolved in water). Oxygen is soluble in water and fish live by breathing dissolved oxygen gas. Dissolved gases do not follow the same rule with regard to temperature as dissolved solids, but on the contrary as the temperature rises, less, not more, of the gas will dissolve.<sup>1</sup>

**Distillation.** — When fluids change to gases at ordinary temperature we speak of the process as *evaporation*. When heat is applied so that the change from fluid to gas is violent we call it *boiling*. When gases are cooled sufficiently, or are subjected to pressure, or both, they *condense* and form liquids again. *Distilling* consists of first boiling a fluid and then cooling the escaping vapor to a liquid. Distillation is very useful in purifying and separating various substances.

<sup>1</sup> The reason that boiled water tastes "flat" is that the heat drives all the dissolved air out of it.

## CHAPTER III

### CHEMICAL NAMES AND FORMULAS. CHEMICAL AFFINITY

**Chemical Names tell the Composition of Substances.** — To make the study of their science as easy as possible, the chemists have tried to give every compound a name that in general tells what its composition is. This can be done, however, only with relatively simple compounds. When we get molecules that contain two or three hundred atoms it is impossible to name them all, but in the more simple compounds the name indicates the atoms, and even in the very complicated ones the name often tells a great part of the story.

Thus, combinations of oxygen are known as *oxides*. Some of the simple oxides already familiar to you are carbon dioxide (the bubbles of carbonated beverages), nitrous oxide (laughing gas), zinc oxide. Most of the elements can form oxides.

Many (but not all) compounds of chlorine are called *chlorides*. It is evident from the name that sodium chloride is a compound in which two elements, sodium and chlorine, have combined. The

same is true of bromides and iodides and sulphides. Each of them is a simple combination of some element with bromine or iodine or sulphur. In general, the name suggests the combination.

**Reason for Using Formulas.** — In the more complicated parts of chemistry short names have to be used for long compounds. But in order to state simply and completely what atoms form each molecule a system of *abbreviations* has been invented. In addition to the name for each compound there is a *formula* that tells in a few letters the chemical structure. In writing formulas each element has a letter or pair of letters which represents it. These abbreviations are used by all chemists of the world; a chemist speaks a sort of international language. It helps greatly in understanding chemistry to know the most important of these abbreviations: —

|                  |                               |
|------------------|-------------------------------|
| Bromine . . Br.  | Iron . . . Fe. (for the Latin |
| Calcium . . Ca.  | Iodine . . I. ferrum)         |
| Carbon . . C.    | Oxygen . . O.                 |
| Chlorine . . Cl. | Nitrogen . . N.               |
| Hydrogen . H.    | Phosphorus . P.               |
|                  | Potassium . K.                |

Because phosphorus was known before potassium it has the initial letter "P" for its abbreviation; potassium must have some other initial and so the



Latin name of kalium is used for potassium and its abbreviation is simply K.

Sodium . . . Na. (natrium)

Silver . . . Ag. (argentum, Latin for silver)

Sulphur . . . S.

**How to interpret Formulas of Compounds. —**  
*Each initial written alone stands for a single atom. When two or more initials are written together they stand for a compound* whose molecule contains as many of each kind of atom as is represented by the little figure written to the right of the letter. For example: KI means a molecule containing one atom of potassium and one of iodine (potassium iodide). The abbreviation  $\text{CO}_2$  means that each molecule of carbon dioxide contains two atoms of oxygen and one of carbon. The formula for silver nitrate is  $\text{AgNO}_3$ , which means that one atom of silver is united with one of nitrogen and three of oxygen. Thus there are five atoms in the one molecule of silver nitrate. The formula tells at once exactly what silver nitrate is.

#### CHEMICAL AFFINITY

**What makes Atoms Unite? —** Why do the atoms unite to form molecules? In order to explain this

scientists have had to assume the existence of a powerful and little understood force known as *chemical affinity*. This tendency to unite with other atoms is very strong in some instances, very weak in others. Thus the tendency of the elements sodium and potassium to combine with other elements is so great that it is extremely hard to keep these substances, even when one gets them, in a pure state. They combine with anything they touch. When thrown into water potassium combines with it so violently as to burst into flames. On the other hand some elements, such as gold and platinum, have very little tendency to unite with other elements and they form only a few compounds and these with difficulty. This is why they are used as jewelry.

**Special Affinities of Different Atoms.** — Not only do the atoms vary in the strength of their unions, but they show peculiar preferences; each atom shows a greater tendency to unite with certain atoms than with others. The laws that govern this chemical affinity are quite definite, so that when a number of different kinds of atoms are mixed together in such a way as to be free to combine, one can always predict with certainty which ones will unite with each other.

Thus if any metal such as iron, or even silver or gold, is put into a watery solution of the element chlorine, the metal will always unite with the chlorine, — never with oxygen or hydrogen, because the chemical affinity of chlorine for all metals is very great. On the other hand, most metals, if kept in water containing no chlorine, or even in moist air, will gradually rust or tarnish, due to union with oxygen.

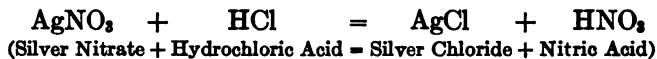
#### THE USE OF CHEMICAL FORMULAS

To show how we can express chemical reactions or changes and think out how they will happen, let us take the action of hydrochloric acid on silver nitrate. Hydrochloric acid contains to each molecule one atom of hydrogen and one of chlorine. Its formula is HCl.

Mix a drop of clear silver nitrate solution in a test tube with a little hydrochloric acid; a thick, white substance or *precipitate* forms at once.<sup>1</sup> Silver has a very powerful affinity for chlorine and when they unite they form silver chloride. This is what the precipitate is composed of.

<sup>1</sup> A precipitate is a solid formed in a solution as a result of chemical action. The fluid can be separated from the solid by filtering through filter paper. When this is done, the clear fluid that comes through the paper is known as the *filtrate*, the solid powder left on the paper is called the *residue*.

The formula which expresses what happens is:—



This says that on adding silver nitrate to hydrochloric acid the silver leaves its combination with nitrogen and oxygen and joins the chlorine, for which it has a greater affinity. The hydrogen which was originally present in the hydrochloric acid being torn from its chlorine unites with the equally deserted nitrogen-oxygen combination to form another new substance which will later be recognized as nitric acid. Thus *formulas show the exchange of atoms between molecules.*

Any compound which contains chlorine united with one other element will act in the same way as hydrochloric acid when brought into contact with a silver compound.

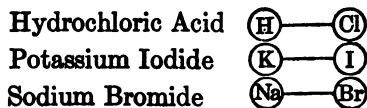
Thus let the student find out what happens if sodium chloride (NaCl) instead of hydrochloric acid (HCl) is mixed with silver nitrate. Write the formula.

#### VALENCE

The reader will have already noticed that in forming compounds *some atoms combine only with one other atom, others join with two, three, or more.* Thus the atom of oxygen unites with two atoms of

hydrogen to form the molecule of water ( $\text{H}_2\text{O}$ ), while the atom of chlorine unites with only one atom of hydrogen to form hydrochloric acid ( $\text{HCl}$ ). This is subject to a definite rule which explains why the molecule of any substance contains always fixed numbers of the same atoms grouped in the same way. This explanation is really another working hypothesis, known as the *theory of valence*.

**Valences are Imaginary Points of Attachment for Other Atoms.** — *Imagine the atom as having arms* by which it can hold on to the arms of other atoms. *Each kind of atom has always a fixed number of arms, or valences, as they are more properly called.* — Thus, for instance, the atoms of hydrogen, sodium, potassium, chlorine, bromine, iodine, have each only *one* arm to hold on to the other atoms with. When they unite with each other these atoms therefore form compounds having two atoms only to each molecule. Picture to yourself the atoms with their imaginary arms : —



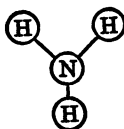
The atom of oxygen as well as that of sulphur has *two* such arms or valences. The atom of nitrogen

has *three* (and in reality it has two extra arms which it occasionally can use, but which in its ordinary combinations it does not use). The atom of carbon has *four* arms.

A knowledge of these facts will enable you to understand much more clearly the reason for the structure of some of the molecules that we have been considering. Thus take, for instance, the molecule of water ( $\text{H}_2\text{O}$ ). In *water* we have the two-armed atom, oxygen, holding with each of its arms to the arm of a one-armed atom, hydrogen, thus:—



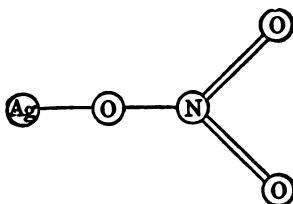
Or consider *ammonia* ( $\text{NH}_3$ ). Here we have the nitrogen atom holding by its three arms to the arms of three atoms of hydrogen:—



Two atoms may often be joined by more than one arm or valence. Thus, for instance, in  $\text{CO}_2$  (carbon dioxide) the carbon atom divides its four arms, giving two to each of the oxygen atoms with which it is united:—



**What is meant by Structural Formulas? —** All the complicated structure of the much larger molecules of the more complex compounds is built up in exactly the same way. Each atom holds to the other atoms by one or more of its available arms. Those formulas which are written out in such a way as to show how each atom of the molecule is attached to the others by the proper number of valences are known as *structural formulas*, because they show what is believed to be the actual structure of the molecule. Thus the structural formula of *silver nitrate*,  $\text{AgNO}_3$ , is: —



Write the structural formula for potassium nitrate,  $\text{KNO}_3$  (niter, saltpeter).

## CHAPTER IV

### ENERGY AND OXIDATION

#### ENERGY

EVEN superficial observation shows that there must be some close connection between chemical changes and such manifestations as heat, light, electricity, and motion. Almost all combustions, for instance, raise the *temperature*, and many of them produce light as well. Any chemical reaction that occurs suddenly may show violent *motion* in the resulting explosion (gunpowder, for instance). And every one knows that the *electric current* comes from the interaction of the chemicals that are put into an electric battery.

And, on the other hand, not only do chemical changes produce heat, light, or electricity, but just as often heat, light, or electricity produce chemical changes. The roasting of coffee, the bleaching of muslin, and the silver plating of household utensils by means of the electric current are everyday instances of this.



**How Different Forms of Energy are Related. —** What is the connection between chemical changes and all these forces? Or perhaps before we try to answer that we should ask: *Is there any connection between these different forces themselves?* There is. They are all of them different *forms of motion*.

The first inkling of this remarkable fact came as far back as the beginning of the nineteenth century, when Count Rumford proved that by continued friction one could produce heat in any amount.<sup>1</sup> Hence, he said, heat is not a material substance, but a mode of motion. Gross motion by friction is converted into motion of molecules. (Before that time heat had been regarded as a fluid.)

**Forms of Energy mutually Convertible. —** And then as a result of a series of wonderful discoveries it gradually became clear that by suitable means *any one of these forms of so-called energy could be converted into any other*. Practical inventions grew out of these discoveries. The steam engine was invented to convert heat into motion. But the heat that drives the steam engine comes from the burning of coal, — a chemical process. So the steam engine is really a machine for converting chemical energy into motion. The motion provided by the steam engine

<sup>1</sup> The heat produced by friction is what lights a match.

in turn can be changed to electricity by the electric dynamo and sent on wires to long distances. And the electric current of the dynamo provides both light and heat or is converted back into motion again at convenient places by the electric motor.

**Conservation of Energy.** — From all this resulted a great generalization (first formulated by Mayer, a German physician, about 1840). It is known as the principle of the *conservation of energy* and is regarded to-day as one of the most fundamental doctrines of all scientific thought. The principle in brief is that *energy can neither be created nor destroyed*, neither come into existence nor be annihilated. When energy seems to have been produced it has really only been changed from some hidden to some visible form; when energy seems to have been lost it has only been dissipated, not destroyed.

**Hidden Energy of Chemical Compounds.** — Now let us go back to our question. What connection is there between chemical change and all these different forms of energy? It is this: *when energy in any form is manifested as the result of a chemical process, that energy must have been lying hidden* in the substances that entered into the chemical process. When coal burns the heat is not newly created, but is energy that has been lying dormant, locked up in

the molecules of the coal for untold ages. And, conversely, *when energy is used to bring about a chemical change, that energy is not lost, but put into the newly formed chemical substances.*<sup>1</sup> And from these substances it can be liberated again either in the same or another form, only by a subsequent chemical change. The energy of the coal was obtained from the sun's rays millions of years ago. All chemical processes either use up or free energy.

**The Animal Body a Machine for Transformation of Energy.** — Of what significance is all this to us? We are interested, first of all, in the care of the human body. "*A living body is a machine, by which energy is transformed, in the same sense as a steam engine is so, and all its movements are to be accounted for by the energy which is supplied to it.*" (Huxley.)

**Measuring Energy.** — As we need standards to measure weight and distance, so also *we need a standard* to measure so universal a commodity as energy. A number of such standards have been proposed and used for special purposes (for instance, the foot pound, the horse power). But the standard in most

<sup>1</sup> Just so work done in lifting a weight is not lost, but can be recovered again if the weight in falling is connected with a pulley. The energy latent in the lifted weight might be compared to the energy in the altered molecule.

general use (and the one most important to us because it is used in measuring the hidden energy of foods) is based on heat. *The unit is the amount of heat needed to raise one kilogram of pure water one degree on the centigrade scale,*<sup>1</sup> and this amount of heat is called a *calorie*.

**The Meaning of "Food Value."** — Thus when we say that a gram of starch has four calories, or a gram of fat nine calories, we mean that the complete burning up of these substances (whether in the test tube or in the body) would produce enough heat to raise, respectively, four and nine kilograms of water one degree on the centigrade scale. Or if we say that a child of one year needs every day seventy calories for every kilogram (one thousand grams) of body weight, we mean that the child needs food which if burnt up would provide that amount of energy. So substances have "food value" in proportion as they supply the body with energy. Water and salts are absolutely essential in the diet, but in this sense they have no "food value."

#### OXIDATION

Energy can be manifested by all sorts of chemical changes; but *the kind of chemical change*

<sup>1</sup> From 0° C. to 1° C.

*which most commonly produces energy is oxidation,* the entering of any substance into combination with oxygen.

**What happens in Oxidation?** — This was discovered by the great French chemist Lavoisier soon after the discovery of oxygen itself in 1774. It was noticed that oxygen was consumed or transformed during the combustion of any substance, and that the weight of the substance (or of its products) was increased by just so much as the weight of the oxygen that disappeared.

*Oxidation may go on slowly,* as in the rusting of iron or the glowing of charcoal. *Or it may go on very rapidly* with the liberation of heat and light. This latter is called *combustion*. Substances which oxidize slowly in the air (which contains only about 20 % of oxygen) will burn brightly if put in pure oxygen. Thus a piece of glowing charcoal or a glowing match will flare up with a brilliant white light for a few moments if dropped into a test tube filled with oxygen (from an oxygen tank such as is used for the sick). This combustion lasts only a few moments, until all the oxygen in the tube has been used up. Or a piece of steel wire (a watch spring), which of course oxidizes only very slowly in the air, will burn with a brilliant white light if heated

to redness in a Bunsen flame <sup>1</sup> and held in a stream of pure oxygen.

**Oxidation may decompose Substances.** — Oxidation may mean merely the attachment of oxygen atoms to other atoms without any very extensive breaking up of molecules; thus when a piece of phosphorus or a piece of sulphur burns in the air, phosphorus or sulphur atoms unite directly with oxygen atoms. *Or oxidation may mean the complete breaking up of complicated molecules* so that the various atoms can combine with oxygen.

An instance of the latter class is the burning of wood. Wood is composed chiefly of carbon and hydrogen, with a very small proportion of oxygen. When wood burns the carbon and hydrogen are split apart, the carbon uniting with oxygen to form carbon dioxide,  $\text{CO}_2$ , the hydrogen uniting with oxygen to form water,  $\text{H}_2\text{O}$ .

**Production of Carbon Dioxide and Water by Burning Wood.** — You can convince yourself of this

<sup>1</sup> The *Bunsen gas jet* is one in which air is allowed to be sucked in with the gas at an opening a few inches away from the flame. The result of this intimate admixture of air and gas is a non-luminous flame, because the oxidation is very complete and there are no luminous particles of unoxidized carbon to give light. An ordinary luminous flame is not so hot and a certain amount of carbon fails to burn and is given off as soot. The burners of our gas stoves are modified Bunsen burners.

by a very simple experiment. Hold a burning match under an inverted wide test tube so as to catch the fumes. Near the neck of the tube little beads of water (condensed steam) are formed on the glass (ordinary smoke contains a considerable amount of moisture). As soon as the match stops burning, quickly turn the tube right side up and pour some limewater into it. The limewater turns milky, due to a precipitate of calcium carbonate formed by the union of carbon dioxide with calcium. (This is the most convenient test for carbon dioxide.<sup>1</sup>)

**The Same Substances are produced by the Human Body.** — Thus the products of the oxidation of anything composed of carbon and hydrogen are carbon dioxide and water. This is just as true of our bodies (which are composed largely of carbon and hydrogen) as it is of the match. Just as  $\text{CO}_2$  and  $\text{H}_2\text{O}$  are given off by the match, they are given off by our bodies. This can be easily proved. Breathe out through a glass tube into a test tube of limewater; the limewater quickly becomes cloudy from the  $\text{CO}_2$  of the breath. The water produced

<sup>1</sup> It is due to this reaction that a bottle of limewater left unstoppered gradually turns cloudy and loses its strength from the traces of carbon dioxide in the air.

by oxidation in our bodies is given off as sweat and urine, and as vapor from the lungs.

**Why we need Air.** — During respiration the *air* (which is practically nothing but *oxygen diluted with about four times its volume of nitrogen*<sup>1</sup>) is drawn into the lungs and deprived of a small part (about 5%) of its oxygen. In exchange it receives the carbon dioxide which the body has to get rid of. The oxygen that is absorbed from the air is taken up by the red blood corpuscles. It enters not into firm chemical union, but into loose combination with the red substance called hæmoglobin in the corpuscles. Hæmoglobin that is carrying oxygen in this way is bright red in color, whereas after it has given up its oxygen to the various organs and tissues it is deep purple. This is the cause for the difference in color of blood flowing from arteries and that flowing from veins.

And so it is oxygen, after it has reached the tissues of the body, that liberates the energy necessary to produce the muscular contractions, the warmth, the nerve actions, and the thousand other manifestations of life.

<sup>1</sup> It also contains small amounts of carbon dioxide and water vapor and traces of a number of other gases.



## CHAPTER V

### ACIDS

**Three Principal Kinds of Compounds.** — As there are only eighty elements, most of the substances we know are compounds. Of the thousands of inorganic or mineral compounds the majority belong to one of three classes: they are acids, salts, or bases. The acids have very striking characteristics in common. They form a sharply defined group. It might be well to begin the study of acids by examining cautiously <sup>1</sup> bottles of a number of common acids (hydrochloric, sulphuric, nitric, acetic). The bottles, though of the same size and contents, vary greatly in weight. The bottle of sulphuric acid is surprisingly heavy.

**Taste.** — If you dissolve a single drop of any of the acids in a glassful of water, you will notice that a strong *sour taste* has been given to the water. All acids in dilute solution taste sour, and *almost all* ● *things that are sour are acid*. Acetic acid is what gives the sour taste to vinegar, citric acid to lemon,

<sup>1</sup> Some of them are dangerous poisons.

phosphoric acid to the "phosphate" at the soda water fountain.

Several of the bottles give off rather irritating fumes (hydrochloric, nitric, acetic acids). This is because these acids are volatile (easily given off in the gaseous form).

**Physical State. Solubility.** — Though, for convenience, we examine the acids in fluid form, or at least in solution, they are not all fluids at ordinary temperatures. Some are solids and others are gases (hydrochloric acid, for instance). All of them can be made either solid, fluid, or gaseous by suitable temperature and pressure. They are all easily *soluble in water*. In fact, they have a special kind of *affinity for water* and some of them unite with it very violently. Thus if a few drops of sulphuric acid are carefully<sup>1</sup> (drop by drop) put into a test tube with a little cold water, the water instantly becomes very hot.

Let us try the effects of some of the acids on certain solid substances and see what we can learn about the characteristics and composition of the acids.

<sup>1</sup> Hold the tube with the opening pointed *away from yourself* and away from any one else. This is a safe rule for all test tube experiments. If the water or acid is hot or the acid is all added suddenly, the mixture may splutter into somebody's face.

**Acids attack Metals.** — Put a ten-cent piece in a test tube with some strong nitric acid and heat very gently.<sup>1</sup> The dime dissolves slowly (as can be determined later by seeing the corroded surface) and gives off little bubbles of clear gas. The solution turns green (due to the fact that the nitric acid dissolves some copper out of the dime; the compounds of copper are mostly green). Set the tube aside and a little later you can return to it and perform an experiment that will convince you that silver is also dissolved in it.

Drop a very small piece of zinc into some strong hydrochloric acid. The zinc dissolves and bubbles of gas come away from it in a lively manner as though the solution were boiling. After a while the zinc disappears entirely.

**Acids form Compounds with Metals.** — In both of these instances a solid substance has been dissolved in an acid. It might be thought that the result was simply a solution of the solid in the fluid like the solution of salt or sugar in water. But this is not so. If we evaporate the salt or sugar solution, we get back simply salt or sugar. But *if we could evaporate the tubes in which the dime and the*

<sup>1</sup> If heated too much, large volumes of intensely irritating brown fumes are given off.

*zinc were dissolved, we would recover not copper, or silver, or zinc, but a green compound of copper called copper nitrate, a crystalline compound of silver called silver nitrate, a white saltlike poisonous compound of zinc called zinc chloride. Furthermore, if we could examine the amount of acid in each of the tubes before and after the addition of the metal, we would find that the acid had diminished. The acid used itself up in attacking the metal and forming the new compounds.*

*The most striking characteristic of the acids, then, is their power of decomposing and dissolving certain other substances, with the formation of new compounds.*

**All Acids contain Hydrogen.** — Note also that in both experiments *bubbles were given off*. If we were to collect and examine these bubbles, we would find in both instances that *they consisted of hydrogen gas*. Hence, since the hydrogen could not have come from the dime or the zinc, it must have come, in each instance, from the acid. Acids contain hydrogen.<sup>1</sup>

And now (since we have not time to completely

<sup>1</sup> Not all acids give off free hydrogen under similar conditions, but there are other methods of proving that all acids contain hydrogen.

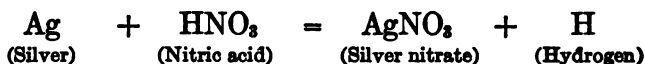
analyze the acids) let us see what we can learn by examining the formulas of a number of acids: —

|                             |                                |
|-----------------------------|--------------------------------|
| Hydrochloric Acid . . . . . | HCl                            |
| Sulphuric Acid . . . . .    | H <sub>2</sub> SO <sub>4</sub> |
| Nitric Acid . . . . .       | HNO <sub>3</sub>               |
| Carbonic Acid . . . . .     | H <sub>2</sub> CO <sub>3</sub> |
| Phosphoric Acid . . . . .   | H <sub>3</sub> PO <sub>4</sub> |
| Hydrocyanic Acid . . . . .  | HCN                            |

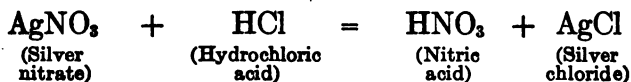
You will notice that besides some element (chlorine, sulphur, nitrogen, etc.) after which the acid is named, and besides oxygen, present only in some of the acids, all the acids have one characteristic in common, — *they all have at least one hydrogen atom.*

**What is peculiar about the Hydrogen in Acids? —**  
 There are many other substances that have hydrogen atoms in their molecules (water, for instance); but the hydrogen atom in the acid molecule is peculiar. It is loosely attached, so that you may think *of the acid as constantly trying to get rid of it.* But the acid can only get rid of the hydrogen atom on one condition, — *namely, if it can replace the gap in its structure filled by the hydrogen atom with some other atom for which the acid has a greater affinity.* It is this peculiarity of replaceable hydrogen atoms that gives all the acids their “acid” characteristics.

**Action of the Nitric Acid on Silver.** — Thus let us take the first experiment above (page 38) — the dissolving of silver in nitric acid. The formula for this reaction is: —



What happened was that the molecule of nitric acid simply threw off its hydrogen atom and replaced it with a silver atom. The excluded hydrogen was given off as bubbles. *The presence of dissolved silver nitrate can be proved* by pouring off the nitric acid in which the dime has partly dissolved and adding to it some hydrochloric acid. At once a dense, curdy white *precipitate* forms and sinks to the bottom of the tube. (A precipitate is any solid that is formed as the result of a chemical reaction in a fluid; usually it is heavy and is “precipitated” down to the bottom of the tube.) If you take a granule of silver nitrate (such as you are already familiar with in the caustic stick), dissolve it in water and add a little hydrochloric acid, you will get the same kind of white precipitate. The formula for the reaction by which the precipitate is formed is: —



This equation shows that the silver has left its attachment to the nitrogen-containing molecule (silver nitrate) and has replaced the hydrogen of the hydrochloric acid. In this test there was a contest between the nitric and the hydrochloric acid for the possession of the silver atom. The hydrochloric acid had a greater affinity for silver than nitric acid had, and the resulting compound, silver chloride, being insoluble, was precipitated down as a solid.

Similarly, *all of the acids have particular affinities* for certain elements or combinations of elements and combine with these rather than with others. The substances with which acids combine in this way are chiefly metals and the combinations or *compounds are known as salts*.

**There are Strong and Weak Acids.** — The solvent powers of some acids, as, for instance, the strong mineral acids, hydrochloric, hydrofluoric,<sup>1</sup> nitric, sulphuric, are very great. Other acids, like phosphoric and carbonic, are relatively weak. Another group of acids, of which acetic acid is an example, is known as organic acids. (See chapter on organic chemistry.)

<sup>1</sup> Hydrofluoric acid is so powerful a solvent that it dissolves even glass, and hence cannot be kept in glass bottles. It is used for etching on glass.

**Decomposing Power of Acids.** — Acids not only combine with those substances for which they have chemical affinity, but in order to get at those substances, they often break down and *disintegrate* other molecules. The acids are therefore very powerful decomposing agents. To illustrate this action, drop a small splinter of wood into a test tube of sulphuric acid and warm gently. The fragment of wood rapidly becomes charred and black and finally disappears completely.<sup>1</sup>

**The Litmus Test.** — There is a very simple *test for the presence of acid* in any solution, — namely, the litmus test. *Litmus* is a colored substance derived from the root of a plant. In the absence of acid it is purple or blue, but *it is turned bright red by any acid*. We generally use pieces of paper which have been soaked in litmus. Dip several such pieces of paper in different acids and all of them turn bright red. It will help you to remember that the red color of litmus indicates acid, if you remember it in connection with the fiery nature of acids.

Acids play a very important part in the chemistry of our body. The most important acid is the hydrochloric acid found in the stomach juice.

<sup>1</sup> Other experiments in which acids are used to split molecules are described in the chapter on carbohydrates.



## CHAPTER VI

### BASES

As peculiar as the acids and yet in their properties entirely different, in fact almost exactly the opposite are the important substances called bases (also called hydroxides or hydrates).

**Properties of Bases.** — Let us examine the watery solutions of a few typical bases, such as : —

Sodium hydrate (caustic soda)  
Potassium hydrate (caustic potash)  
Ammonium hydrate (ammonia water)  
Calcium hydrate (limewater)

We notice that when applied to the skin they give it a peculiar *soapy feeling*. Some of them (sodium potassium, ammonium hydrate<sup>1</sup>) applied to mucous membranes are strong irritants and *corrosive poisons*. When diluted well (for safety) they are found to have an unpleasant *soapy taste*. Tested with litmus, they are found to do exactly the opposite to acids, — *they turn litmus a deep blue* (whether it was red or

<sup>1</sup> These are the bases whose characteristics are most pronounced, — the strong bases, — and are known as *alkalies*.

purple to start with). This is the best test for bases ; anything that turns litmus blue is basic or *alkaline* (the two terms can practically be regarded as interchangeable).

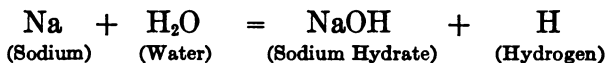
But *the most important property of the bases is their power of neutralizing acids*. When strong bases and acids are mixed together they react violently — almost explosively — with each other. If potassium hydrate, for instance, is mixed with hydrochloric acid, the mixture is found to have become very hot, and if enough of the alkali has been added the peculiar properties of the acid will be found to have entirely disappeared.

**Decomposing Powers.** — The alkalies have powerful *dissolving and decomposing properties* also, though generally to a less extent than the acids. It is this property that makes them so useful as *cleansing agents* (ammonia, washing soda, lye, etc.). Sodium and potassium hydrate actually have some decomposing effect (though it is slight) on glass ; so that if you shake up a bottle of one of these substances that has been standing on the shelf for some time, you will see in it shavings of glass dissolved by the fluid from the inside of the bottle.

What gives these bases their peculiarities? Why do they neutralize acids? In other words, what is

their chemical composition? We can find out best if we manufacture some alkali ourselves. Let us make some sodium hydrate.

**Sodium combines with Water.** — Throw a small piece of metallic sodium<sup>1</sup> into a beaker of water; it floats on the surface, melts (from the heat of the reaction), rolls about, and rapidly disappears; at the same time it seems to evolve bubbles of gas. After the sodium has disappeared in the water the solution is found to be strongly alkaline and to have all the properties of caustic soda (sodium hydroxide); and if the gas given off is collected in an inverted test tube, it can be shown to be hydrogen gas. In other words, sodium hydrate has been formed by the sodium driving some of the hydrogen out of the molecule of water. This is shown in the formula:—



So in general *bases are formed by the combination of some metal with water*; and in fact all the metals can combine in this way to form hydroxides (though most of them do not unite directly and violently as sodium does).

<sup>1</sup> Ordinarily kept in a bottle of petroleum because the sodium oxidizes rapidly in the air and petroleum is one of the relatively few things it does not combine with.

**The Atom Group OH.** — Now let us compare the formula of sodium hydrate with the formulas of a couple of other bases, in order to determine what the common factor is : —

|                             |                                   |
|-----------------------------|-----------------------------------|
| Sodium hydrate . . . . .    | NaOH                              |
| Potassium hydrate . . . . . | KOH                               |
| Ammonium hydrate . . . . .  | NH <sub>4</sub> OH                |
| Calcium hydrate . . . . .   | Ca(OH) <sub>2</sub>               |
| Magnesium hydrate . . . . . | Mg(OH) <sub>2</sub>               |
| Iron hydrate . . . . .      | Fe <sub>2</sub> (OH) <sub>3</sub> |

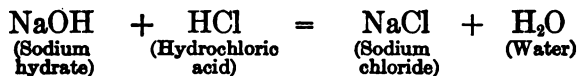
It is apparent at once that *every one of these bases contains the atom group oxygen-hydrogen (OH)*. It is, then, this OH group, combined with a metal,<sup>1</sup> that makes a base.

**How can we explain the Effect of Bases on Acids ?**  
— In the OH group the oxygen and hydrogen atoms are very firmly bound together so that when the molecule is broken up in any chemical change the split never comes between them, but always between the OH group and the metal atom. The metal atom in alkalies (or bases) can be thought of as always ready to be split off and replaced by a hydrogen atom,

<sup>1</sup> Ammonium hydrate is an apparent, not real, exception. Though nitrogen and hydrogen themselves are not metals, when united in ammonia they show the chemical behavior of a metal.

just as the hydrogen atom in acids is always ready to be replaced by a metal atom. Thus when an alkali and an acid are brought together the conditions for an exchange are perfect. Each has the atom that the other desires. This explains the neutralizing effect of bases on acids.

**Neutralization.**— Take, for instance, what happens on mixing sodium hydrate with hydrochloric acid : —



Hydrochloric acid rejects its hydrogen atom in exchange for the metal sodium for which it has such a strong affinity. The alkali (sodium hydrate) rejects its metal (sodium) atom in exchange for the hydrogen atom freed from the acid and forms water. You see, then, that the alkali and the acid on being mixed formed sodium chloride (salt) and water. The salt is neutral ; it is neither acid nor alkaline. Litmus paper dropped into it does not change color at all.

This experiment, the *neutralization of an acid by an alkali, and the resulting formation of a salt* is simple and can be performed by any student. Test some weak hydrochloric acid with litmus paper. It turns the litmus paper bright red. Weak sodium hydrate turns litmus paper blue. Add the sodium hydrate

solution to the hydrochloric acid little by little, testing with litmus paper after each new addition to see whether the solution still turns the paper red. A point is finally reached where the paper no longer changes. This is *the neutral point* and the solution is no longer a solution of acid or alkali, but a solution of sodium chloride, — ordinary table salt, — and can be safely identified by the sense of taste. The reaction which has taken place is the same as that shown in the formula above. By mixing a powerful acid and a powerful alkali neutral, harmless table salt has been formed.

Bases play an important rôle in the chemistry of our bodies. The blood is weakly alkaline, and certain of the digestive juices (bile and pancreatic juice) are decidedly alkaline. (See chapter on digestion.)

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## CHAPTER VII

### SALTS

THE salts are the third great group of compounds. They are more numerous in the world and play a more important part in our bodies than either acids or bases. Although they have no true nutritional value (*i.e.* supply no energy), salts are absolutely indispensable in the diet of all animals.<sup>1</sup>

From the two preceding chapters their chemical composition is already clear. *They are all formed by the union of an acid with a metal.* The metals which combine with acids to form salts are not only the familiar metals like iron and silver, but also certain others such as sodium, potassium, calcium, and magnesium. Besides this there are some groups of atoms, themselves not metals, but which combined act like metals. The most important of these is ammonia ( $\text{NH}_3$ ). In the study of organic chemistry

<sup>1</sup> So essential is salt in human food that the high tax put on salt by a rapacious government was one of the immediate causes of the French Revolution.

we will learn that there are many other such combinations.

Salts are more numerous than acids because for each acid there are as many different salts as there are metals that the acid can combine with. Thus, for instance, consider the more familiar salts of the common acids:—

Hydrochloric acid forms *chlorides*.

|                                           |                     |
|-------------------------------------------|---------------------|
| Sodium chloride (ordinary table salt)     |                     |
| Potassium chloride (present in the blood) |                     |
| Iron chloride                             | } all used as drugs |
| Calcium chloride                          |                     |
| Ammonium chloride                         |                     |
| Mercury bichloride                        |                     |

Sulphuric acid forms *sulphates*.

Magnesium sulphate (Epsom salts)  
Sodium sulphate (Glauber's salts)  
Calcium sulphate (plaster of Paris)  
Copper sulphate (used as a cauterizing agent)  
Iron sulphate (used as a drug)  
Zinc sulphate (disinfectant and cauterizing agent)

Nitric acid forms *nitrates*.

|                                      |                     |
|--------------------------------------|---------------------|
| Sodium nitrate                       | } all used as drugs |
| Potassium nitrate (niter, saltpeter) |                     |
| Bismuth subnitrate                   |                     |
| Silver nitrate                       |                     |



Carbonic acid forms *carbonates*.

|                                                                    |                    |
|--------------------------------------------------------------------|--------------------|
| Sodium carbonate (washing soda)                                    | } used medicinally |
| Sodium bicarbonate                                                 |                    |
| Ammonium carbonate                                                 |                    |
| Bismuth subcarbonate                                               |                    |
| Calcium carbonate (which constitutes marble, chalk, and limestone) |                    |

Phosphoric acid forms *phosphates*.

Sodium phosphate (present in the blood, used as a drug)  
Calcium phosphate (which constitutes the hard part of bones)

There are innumerable other important salts formed by the action of various acids on metals in exactly the same way.

**Bromides and Iodides.** — Thus the elements bromine and iodine are very much like the element chlorine and form acids corresponding in name and behavior to hydrochloric acid.<sup>1</sup> The salts formed from bromine are known as *bromides*. Sodium, potassium, and ammonium bromides are important drugs. The salts formed from the iodine are

<sup>1</sup> The three elements, chlorine, bromine, and iodine, behave very much alike and constitute a group of elements known as the *halogen elements* (because their salts were first derived from the sea or from seaweeds; the word "halogen" is a Greek word meaning "coming from the sea").

known as *iodides*, such as potassium iodide (KI), and ammonium iodide.

**Importance of Salts in the Body.** — Salts play many and varied parts in our body. Thus our blood is practically salt water in which are dissolved some albumin and sugar and in which are suspended or floating around the little red corpuscles which make the blood opaque and red.

A nurse should not only be acquainted with the use of *normal salt solution*, but also should understand why it is so important that this have exactly the right strength, namely, 0.6 % to 0.9 %. The reason is that this strength is the same as the strength of the salt solution of the blood.

**Effect of Distilled Water on Blood.** — It is interesting to see what happens to blood when it is deprived of its salt. Take a test tube containing some sheep's blood obtained from the slaughterhouse. It is opaque and dark red in color like the blood that flows from a vein at an operation.<sup>1</sup> Pour

<sup>1</sup> This dark color incidentally is due to the fact that the blood has been standing in a narrow test tube open only to the air at the top and that it has used up its oxygen, for if you pour a little of the blood into another test tube and shake it up well so that it can absorb oxygen from the air, it turns bright red, but is still opaque. In obtaining the blood at the slaughterhouse it has to be defibrinated, i.e. beaten or shaken up with glass beads, in order that it will remain fluid.

a little of the blood into a test tube containing some normal salt solution; the blood retains the same opaque appearance. But pour some of the blood into a test tube of ordinary water or of distilled water and the appearance is entirely changed. In a moment or two the tube instead of being opaque becomes perfectly transparent.

What has happened is that in the absence of the salts (or what is the same thing, when the salts were greatly diluted so as to be present in only a little strength as compared with normal salt solution) the red blood cells became completely dissolved and destroyed. This is called the "laking" of blood, or *hæmolysis*. (Lysis means dissolving.) It is because of the danger of hæmolysis that plain or distilled water cannot be used for intravenous or subcutaneous infusions, but saline solution has to be used.

What is true of the red blood cells is also true, in large part, of the other body cells. They are injured or killed by contact with plain water or with water that contains insufficient amount of salt. Actually all of our body cells, excepting those at the surface of the body, are bathed and live in salt solution.

**Functions of Special Salts.** — Each of the salts has important special functions in the body. Thus

*calcium chloride is absolutely essential for the clotting of blood*; if we did not have it, our blood would never clot and we should bleed to death from the slightest cut. This is the reason why calcium compounds are used as drugs in certain diseases in which the blood does not clot properly.

**Basic and Acid Salts.** — *Not all salts are neutral in reaction.* Some are alkaline or acid. For instance, the carbonate and bicarbonate of soda are alkaline (and are used medicinally to neutralize excess of hydrochloric acid in the stomach). Their alkalinity is due to the fact that they consist of a very strong alkaline metal (sodium) in union with a very weak acid (carbonic acid). On the other hand acid-sodium phosphate (the best drug known for the purpose of making the urine acid) derives its acid properties from the fact that in its formation phosphoric acid does not get all of the sodium it could unite with, *i.e.* is incompletely neutralized. When phosphoric acid gets all the sodium it can combine with it forms the ordinary sodium phosphate used as a laxative.

## CHAPTER VIII

### ORGANIC CHEMISTRY

A HUNDRED years ago, when people were first studying such things earnestly, it was noticed that there was a large group of substances entirely distinct from any of the substances we have mentioned so far. The substances of this group were all *derived directly or indirectly from plant or animal organisms* and hence were called "organic" (as distinguished from inorganic or mineral substances).

**Organic Matter completely Combustible.** — They were peculiar in that they were all *easily combustible*, and that when heated they would first char (thus revealing the presence of carbon as one of their constituent elements) and would then finally burn up completely *without leaving any ash or residue*.

(Compare in this regard the behavior of a typical mineral substance, table salt, and a typical organic substance, sugar. Heat a grain of sodium chloride and a grain of cane sugar side by side on a platinum dish over a Bunsen flame. The sugar turns black

and disappears; the salt simply melts, and remains as a solid mass after cooling.)

**Elementary Composition.** — When the fumes given off were examined they proved to consist chiefly of carbon dioxide and water. Sometimes oxidized forms of nitrogen, sulphur, or phosphorus were obtained also. (It is noticed that all these elements are such as burn very readily and have volatile oxidation products.) Thus it came to be recognized that *organic compounds are made of carbon, hydrogen, and oxygen with occasionally the addition of nitrogen, sulphur, or phosphorus.*

[ But here progress was halted for a long while. The organic substances seemed to defy more exact analysis. And especially it was found impossible to manufacture any of them out of the elements. Apparently they could only be produced by the living cell. It was thought that this must be due to some sort of "vital force" which no one at that time thought of identifying with "chemical affinity."

**Organic Substances not limited to Living Things.** — But this difficulty was presently overcome. Beginning with the epoch-making synthesis of urea (a nitrogen containing organic substance found in urine) from the elements, by Wöhler in 1828, the

organic substances have one by one been put together by scientists in the laboratory. *The old idea that organic substances are peculiar to living matter had to be given up.* And to-day, out of over one hundred thousand organic substances known, the great majority have been made by man and are never found in living organisms.

**What is Synthetic Chemistry?** — This wonderful development of *synthetic chemistry* — of the making of new and ever new organic compounds — has played an enormous part in the scientific progress and the industry of modern times. To-day we hardly go through an hour of our lives without using some of these marvelous new substances, new drugs, dyes, flavors, perfumes, fabrics, chemicals, even foods.

**Biological Chemistry.** — Furthermore, with the development of organic chemistry it was possible to begin the study of the *chemistry of life*. It was found that the body is a chemical laboratory with all sorts of intricate changes constantly going on. And although this new branch, biological chemistry, is still in its beginnings, it has already contributed greatly to our understanding not only of the normal processes of the body, but also of the changes in disease. There is a whole group of diseases, such as

gout, diabetes, uræmia, due solely to disturbances of the chemical processes of the body. (These are called *diseases of metabolism*.)

**Different Compounds may have the Same Elements.** — But it must not be thought that this progress was easy. The deciphering of the organic molecule encountered the most baffling difficulties. For not only was it found that most organic substances were made of the same few elements, but it was often discovered that a number of substances, each one having properties widely different from the others, would all on analysis turn out to have exactly the same number of carbon, oxygen, and hydrogen atoms. Thus there are actually eighty-two different substances known having the formula  $C_6H_{10}O_2$ .

*How is it possible to have so many different substances with the same formula?* The answer to this riddle dawned gradually on the chemists, beginning about 1823 with the great Liebig and Wöhler. It is the greatest discovery of organic chemistry, namely, that the properties of a substance depend not only on the kind and number of its atoms, but also (and especially) on the relative positions of the atoms in the molecule.

**Structural Chemistry.** — Thus organic chemistry has become a study of the *architecture of the mole-*



*cule*. Each atom has as definite a place to fill in the molecule as each brick and beam in a house. Often if a single important atom is displaced, the whole molecule disintegrates.

The unraveling of the intricate plans of the organic molecules has proceeded on two routes: first, by the analysis of known substances; and, second, by putting already known substances together and making new substances.

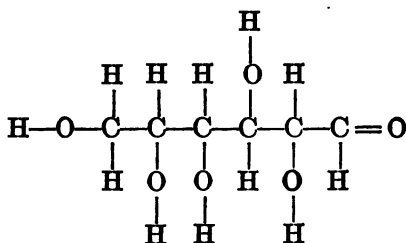
In the former or analytic method the chemist first finds out how much carbon, hydrogen, and oxygen the substance has and what simpler compounds are obtained when the substance is decomposed. And then, knowing the combining power (valence) of each kind of atom, he tries diagrams of all the possible positions in which the atoms could be linked together. Often he is unable to decide which of several diagrams corresponds truly to the molecule he is studying until he has succeeded in imitating the molecule by synthesis (building up). The man who builds a house knows where all the beams and stones lie.

**Importance of Carbon.** — As more and more of these diagrams were deciphered one thing became clear: *the organic molecule is built up around the carbon atom*, or rather around groups and chains

of carbon atoms.<sup>1</sup> For it was found that the atom of carbon has the remarkable property (not possessed by the atom of any other element) of combining — holding hands — with itself.

So the four valences or arms of the carbon atom,  $\begin{array}{c} | \\ -\text{C}- \\ | \end{array}$ , are really the key to all the complications of organic chemistry. For when two carbon atoms

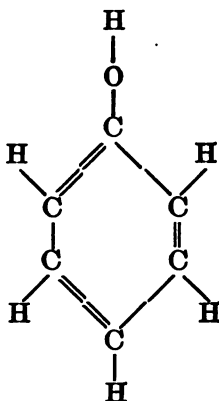
are attached to each other thus,  $\begin{array}{cc} | & | \\ -\text{C} & -\text{C}- \\ | & | \end{array}$ , they need use only one each of their valences. This leaves all the other arms free to combine with other atoms of carbon, oxygen, hydrogen, or other elements. So the molecules of organic substances are built up around chains of carbon atoms linked together like this:—



(Plan of the molecule of grape sugar)

<sup>1</sup> For this reason organic chemistry is sometimes described as the chemistry of the compounds of carbon.

or around rings of carbon atoms like this: —



(Plan of the molecule of phenol, — carbolic acid <sup>1</sup>)

Such formulas, of course, are not representations of actually seen arrangements, but, like the atoms and molecules themselves, are theories; they are accepted because they explain the behavior of the substances.

**Organic Acids.** — Many organic compounds have either acid or basic properties like the inorganic acids and bases referred to in earlier chapters (Chapters V and VI). The acid properties are all due to the

<sup>1</sup> Substances built up on this “ring” plan belong to a group known as the *aromatic group* of substances, because of the strong odors or tastes of many of them. Some other members of the group are camphor, menthol, benzol, turpentine, quinine, salicylic acid, benzoic acid, phenacetine, indigo.

same replaceable hydrogen atom which gives the acid properties to the mineral acids. And, similarly, when these atoms are replaced, salts result. Thus from the well-known *organic acids*, acetic acid (vinegar), lactic acid (sour milk), tartaric acid (grapes, baking powder), oxalic acid (many vegetables), citric acid (lemons) are formed organic salts known, respectively, as acetates, lactates, tartrates, oxalates, citrates. The most important of the organic acids are the so-called "fatty acids" (see Chapter on Fats), such as acetic, butyric, oleic acids.

**Organic Bases.** — Among the organic substances with more or less *basic properties* (*i.e.* neutralizing acids) the *alcohols* are very important.<sup>1</sup> They have the same atom group, OH, which we found in the inorganic bases like sodium hydrate (NaOH) or ammonium hydrate (NH<sub>4</sub>OH). Some of them have several of these OH groups. Thus ordinary glycerin is an alcohol with three OH groups in its molecule so that it can neutralize three different acid molecules at one time. (See Chapter on Fats.)

Another group of organic bases is the *alkaloids*, — substances like morphine, codeine, cocaine, strychn-

<sup>1</sup> For reasons which cannot be gone into here the alcohols do not turn litmus blue and lack certain other "alkaline" properties.

nine, and atropine, — derived from plants and used as drugs. They all form salts such as morphine sulphate, cocaine hydrochloride, etc.<sup>1</sup>

There are three groups of organic substances which dominate the chemistry of food and of the body. These are carbohydrates, fats, and proteids. They will be discussed in the succeeding chapters.

<sup>1</sup> See Blumgarten, "Materia Medica for Nurses."

## CHAPTER IX

### CARBOHYDRATES

THE *sugars and starches* form a large part of the staple food of man. There are many different kinds, but they all resemble each other both as to chemical constitution and as to the functions they perform in the living organism. On this account they are all grouped together under the name of carbohydrates. The carbohydrates are the first of the three great classes of food and body substances which we are to study.<sup>1</sup>

**Of What Use are Carbohydrates?** — The principal function of carbohydrates, both in plants and animals, is to *provide energy* by being oxidized. There are many circumstances, however, under which both plants and animals need to store away energy for future consumption. Under these circumstances the *plants store away their energy chiefly in the form of carbohydrates*, the animals chiefly in the form of

<sup>1</sup> This book is intended to give the principles underlying the study of dietetics. For a practical discussion of different foods see McIsaac, "Hygiene of Food."

fat. Thus the starch packed away in the roots, the sugars treasured up in the fruits, are reserves on which the plant draws in time of need. In the animal body the fat performs this storehouse function, and carbohydrates, though they form a large part of the food, are used up almost as quickly as they are taken.

**What Elements form Carbohydrates?** — A glance at the chemical formulas of carbohydrates will show why they serve so well as sources of energy. They are all composed of *carbon, hydrogen, and oxygen*, and the hydrogen and oxygen are always present in the same proportion as in water, namely, two atoms of hydrogen to every one of oxygen. Thus grape sugar is  $C_6H_{12}O_6$ ; cane sugar,  $C_{12}H_{22}O_{11}$ . Note this ratio, — twice as many hydrogen as oxygen atoms; it is significant. It means that the hydrogen is enough to exactly satisfy the oxygen already in the molecule; *thus all the carbon can combine with oxygen and provide energy*. The products of the oxidation are therefore carbon dioxide ( $CO_2$ ) and water.

**Three Classes of Carbohydrates.** — There are three chief classes of carbohydrates: (1) the *simple sugars or monosaccharides*, very soluble and digestible and having always six carbon atoms to the molecule; (2) the

*double sugars or disaccharides*, almost as soluble and digestible and having always twelve carbon atoms; and (3) the *polysaccharides or complex carbohydrates*, dissolved and digested with much more difficulty and having large numbers of carbon atoms to the molecule.

#### I. MONOSACCHARIDES (SIMPLE SUGARS)

Dextrose (glucose, grape sugar)  
Levulose (fruit sugar, fructose)

**Glucose** is found in plants and fruits as well as in the blood, the muscles, and the liver of animals.

**Levulose** is found in sweet fruits and is especially abundant in honey.

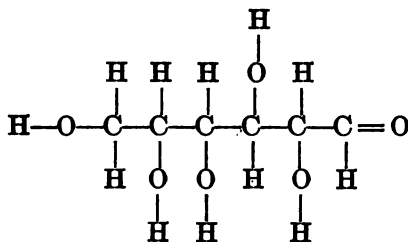
**The Arrangement of the Atoms determines the Properties of the Substance.** — There is no class of substances which illustrate more beautifully and simply than the monosaccharides how a slight difference in the position of the atoms in the molecule may change the nature of a substance. All the monosaccharides<sup>1</sup> have exactly the same composition; they are all  $C_6H_{12}O_6$ . Not only this, but they are all built on the same general plan, — a chain of

<sup>1</sup> There are many more than the two monosaccharides mentioned, but here, as under each heading, only the examples that are of practical importance are given.



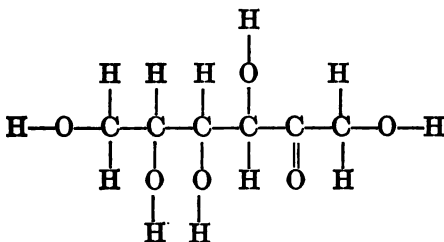
six carbon atoms, to whose side arms (valences) are attached the hydrogen and oxygen atoms. Nevertheless, the different sugars differ from each other in all their properties.

Thus consider grape sugar and fruit sugar. Grape sugar (dextrose) is the form in which sugar exists in the human body; it circulates in the blood and is found in the muscles; if it is injected into the body, it is all utilized (unless injected in very great excess). Levulose, on the other hand, is foreign to the blood and tissues. If it is injected, most of it is promptly thrown out again by the kidneys. It is much sweeter than dextrose. Likewise the two differ markedly in their chemical properties.<sup>1</sup> Yet compare the plan of grape sugar and of fruit sugar :



Grape Sugar

<sup>1</sup> If a beam of a peculiar kind of light called polarized light passes through a dextrose solution, it is twisted to the right, if through a levulose solution, to the left. This remarkable property, which is due to the conformation of the molecules, is used in detecting and measuring sugars and other substances.



Fruit Sugar

The two are so nearly alike that by simply shifting the position of two hydrogen atoms they could be made identical.

The properties of the simple sugars will be discussed together with those of the double sugars.

## II. DISACCHARIDES

Sucrose (cane sugar <sup>1</sup>)

Lactose (milk sugar)

Maltose (malt sugar)

**Cane sugar** occurs not only in the sugar cane, but in beets, maple sugar, honey, and many other vegetable products.

**Milk sugar** is found in the milk of all mammals. It is less sweet and less soluble than cane sugar.

<sup>1</sup> Sucrose (sometimes called saccharose) should not be confused with saccharine, an intensely sweet substance used for flavoring sugar-free, diabetic foods. Saccharine is not a carbohydrate and is not nutritious. It is chemically one of the aromatic substances (like carbolic acid), but is not poisonous.

**Maltose** is a sugar derived artificially from starches by digestion or chemical splitting. Ordinarily, it is made from starch by the digestive action of a substance obtained from sprouting barley grains and called *malt extract* or *diastase*. How this substance works will be explained in the Chapter on Digestion. Maltose is a valuable food and is the chief constituent of such preparations as malt soup, Mellin's food, malted milk.

The double sugars, or disaccharides, are so called because their molecules consist of two simple sugar molecules linked together; so that the formula of all disaccharides is  $C_{12}H_{22}O_{11}$ . The various double sugars differ from each other in being composed of different simple sugars. Thus the molecule of cane sugar contains a molecule of dextrose and one of levulose, while the molecule of maltose contains two dextrose molecules.<sup>1</sup>

<sup>1</sup> After the student is acquainted with Fehling's test for sugar (see below, page 74) a simple experiment can be done to prove that double sugars contain simple sugar molecules. It happens that cane sugar, a disaccharide, does not give Fehling's test, while all the simple sugars do. Hence if cane sugar can be split into its two constituent molecules, dextrose and levulose, these will give Fehling's test.

First boil some cane sugar with Fehling's solution: there is no reduction. Now put a little cane sugar in a test tube with some strong hydrochloric acid and heat gently. Neutralize the acid

## PROPERTIES OF THE SUGARS

The simple and the double sugars have certain properties more or less in common. They are all very *soluble*; they can be obtained as *crystals*; they all taste more or less *sweet*; they are very *digestible* and highly *nutritious*. Perhaps their most interesting characteristic is their property of *undergoing fermentation*.

## FERMENTATION

The lowly and simple forms of life, the *bacteria*, the *molds*, and the *yeasts*, have, after all, the same basic requirements as the higher forms. They must breathe and they must feed. Very many of them are specially adapted to use carbohydrates as their chief food. In so feeding they do the same thing as the higher organisms, they *oxidize* the carbohydrates. And the final products of this oxidation are the same, — *carbon dioxide and water*. This decomposition of carbohydrates by bacteria or yeasts is known as fermentation.

(see page 48) with some 30 % sodium hydrate and then test a little of the fluid with Fehling's solution. The result is complete reduction. The acid has split the double molecule to its component simple sugars. The same kind of molecule splitting happens in the digestion of every disaccharide. (See Chapter on Digestion.)

**Experiment showing Action of Yeast on Dextrose.**

— To demonstrate fermentation, mix a little piece of baker's yeast with some glucose solution, and with the mixture fill one of the small tubes known as Einhorn fermentation tubes. This is a U-shaped glass tube, one limb of which is closed on top so as to collect gas bubbles. Let the tube stand in a warm place for a day and then examine it. Bubbles of carbon dioxide will have collected in the closed end of the tube, and the amount of this gas can easily be measured off from a scale engraved in the outside of the tube. From this amount we can easily tell how much sugar was originally dissolved; for as each carbohydrate molecule has six carbon atoms, and each carbon atom gives rise to one carbon dioxide molecule when fermented, the amount of carbon dioxide is proportional to the amount of sugar.<sup>1</sup>

The production of gas bubbles by yeast growing on carbohydrates is the principle underlying the "raising" or leavening of bread.

**By-products of Fermentation.** — But our interest in fermentation does not stop here. *What is impor-*

<sup>1</sup> This method is actually used to estimate approximately the amount of sugar in the urine of diabetes cases. The scale on the Einhorn tube reads directly in percentages of sugar.

*tant about fermentation is not so much the end products as the by-products.* For in fermentation (just as in the body) substances are not at once and completely oxidized, but the molecules are first broken up into partly oxidized fragments, and then these are further oxidized to carbon dioxide and water.

**Alcoholic Fermentation.** — These intermediate products are different for each kind of carbohydrate and for each kind of bacterium or yeast. Thus the chief by-product of many kinds of fermentation is *alcohol*; and each kind of alcoholic beverage is the result of fermentation of the carbohydrates in some particular kind of grain or fruit, by a microorganism that is specially adapted for the purpose.<sup>1</sup>

**Lactic Acid Fermentation. Vinegar.** — The by-products in many kinds of fermentations are organic acids, such as acetic, lactic, and butyric acids. Thus in the manufacture of kumiss and matzoon and of various kinds of sour milk and cheese *lactic acid* is produced. The production of vinegar is an acetic fermentation (*i.e.* a fermentation by bacteria which

<sup>1</sup> If the wrong germ gets in, the wine spoils. Thus the whole modern science of bacteriology started in the effort of Louis Pasteur to discover why the wine soured in a certain wine-growing district in France. The discovery of a germ as the cause of a "wine disease" led him to search for germs as possible causes of human disease.

produce acetic acid). There are hundreds of manufacturing processes which depend on various kinds of fermentation.

**Gastro-intestinal Fermentation.** — When fermentations occur in the intestinal tract the acids produced are often very irritating and cause digestive disturbances. Our chief means of combating such troubles is careful regulation of the carbohydrates in the diet.

#### TESTS FOR SUGARS

It is often necessary to test for sugar. This is done, for instance, in order to determine whether a patient has *glycosuria* (glucose in the urine, the chief symptom of diabetes). The fermentation test with yeast described above is frequently used.

More delicate and reliable than the fermentation test are chemical tests based on the great avidity of certain sugars for oxygen. These sugars have the power of *reduction*, *i.e.* the power of taking some of the oxygen away from other compounds. The best known of these tests is the *Fehling's test*, in which the sugar is made to "reduce" an oxidized copper salt to a form containing less oxygen.

**Fehling's Test for Sugar.** — Fehling's test is performed with two solutions. The first, known as

Fehling's copper solution, is a light blue solution of copper sulphate. The other is a strong alkaline solution called Fehling's alkaline solution. Equal quantities of the two are mixed together in a test tube; the result is a beautiful deep blue fluid; if this solution is boiled, it retains its color. But if a little dextrose (or some urine containing dextrose) is added, and the mixture is boiled again, a thick, reddish yellow precipitate forms. This is reduced copper oxide, — a copper compound from which some of the oxygen has been withdrawn.

Sometimes in pregnant or nursing women milk sugar appears in the urine. This gives the same reduction in Fehling's test as does dextrose. But as lactose is not fermented by yeast, while dextrose is, we have only to do the fermentation test to make sure that the patient has not diabetes.

### III. POLYSACCHARIDES

Starch

Dextrin

Glycogen (animal starch)

Cellulose (vegetable fiber)

The polysaccharides are important foods. Their molecules contain *great numbers of sugar molecules* compactly linked together. When these *large mole-*



*cules* enter the digestive tract they have to be broken down to simple sugars before they can be used for nutrition. (See Chapter on Digestion.)

**Proof that Starch is made up of Sugar Molecules.** — The fact that the polysaccharide molecule is really built up of sugar molecules can be demonstrated by boiling some starch paste a few minutes in hydrochloric acid, then cooling and neutralizing the acid with sodium hydrate. Before the boiling the starch fails to give any change with Fehling's test. After boiling it completely reduces Fehling's solution. Glucose and maltose have been produced from the starch.

**Why Starch needs Cooking.** — Starch is the form in which most plants store up their energy. It is not soluble in water, but can be made into a paste by boiling. In its natural form it occurs in little *granules* of microscopic size. Under the microscope each granule is seen to be composed of *concentric layers* like an onion. The layers are separated, it is believed, by very fine films of another carbohydrate, cellulose, which is extremely difficult of solution or digestion. This is the reason that it is so important that starchy things prepared for human food be well cooked: in the process of cooking the heat splits open the starch granules and the starch be-



tween the layers of cellulose can be reached by water or by digestive juices.

**Iodine Test for Starch.** — If a drop of any solution containing iodine is added to starch, a deep blue-black color is produced. This color can be shown by adding tincture of iodine to starch direct or by putting a drop of it on the cut surface of a potato or piece of bread. The color is not given by any other substance, and gives us a valuable method of detecting starch. For instance, with iodine we can tell whether gluten foods, claimed to be starch free, are really so.

**Dextrin** (a polysaccharide not to be confused with dextrose, a simple sugar) is a product of the beginning chemical splitting up of starch by acids, or the partial digestion of starch by malt extract or digestive juices. Thus it is seen that as the starch molecule is split up there are produced the successively smaller fragments, dextrin, maltose, and dextrose. The molecules of dextrin contain still a great number of sugar molecules, but not nearly so many as starch itself. It is *more soluble* than starch, *more digestible*, and it does not give a blue color on the addition of iodine, but either a mahogany-brown color or no color at all. It is a valuable food. It has a pasty consistency and is often used as a gum.

**Glycogen (animal starch)** is found in the *liver* and *muscles* and is the form in which carbohydrates are temporarily stored in animals. It is on account of the large amount of glycogen in liver that liver is forbidden for those diabetic patients who have to be on a strict carbohydrate-free diet. Glycogen is very similar to starch in its appearance and properties, but is more soluble.

**Cellulose** is the carbohydrate which forms the fibrous or *woody* part of plants. It is the chief constituent of *cotton*, *linen*, and *paper*. It is *very insoluble* and (by human beings) very indigestible; but the digestive tracts of the herbivorous (*plant-eating*) *animals break it down* to its constituent monosaccharides and utilize it as food. It is possible now to make human food (glucose) from it by treating it with strong acids. (This can be demonstrated by heating a little piece of wood with sulphuric acid, cooling and neutralizing and testing for sugar with Fehling's solution.)

In the study of digestion it will be seen that the same breaking down of complex food molecules into simpler molecules, which in the test tube we can bring about with the aid of powerful reagents, can be performed in the body by means of such harmless substances as saliva and pancreatic juice.

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## CHAPTER X

### FATS

**Fat a Source of Energy.** — As explorers go toward the north and south poles they notice that plant life gradually dies out. Animals venture much farther into these frozen regions than plants do. And one thing is common to all these animals that brave the polar cold: their bodies are saturated with fat. It is this that makes life possible for them, not (as is often thought) by providing a warm coating, but by supplying a constant source of highly combustible fuel to keep up the body temperature. The Eskimo knows the *warmth-giving value of fat* and lays up large stores of it for his winter sustenance.

**The Storing away of Energy.** — Just as carbohydrates are the principal form in which plants store up their reserve energy, fats are the arsenal of chemical energy in the animal body. Animals may simply lay away in their tissues the fat which they eat and do not need for oxidation at the time, or, as a result of

the wonderful chemical transformations the body can perform, they may convert other forms of nourishment, such as carbohydrates and proteids, into fats. Persons who eat much sugar (candy), for instance, tend markedly to adiposity. The sugar in excess of the actual energy needs of the body is retained not in the form of sugar, but of fat.

**Fats give more Heat than do Carbohydrates.** — Indeed in this regard the chemistry of the animal body is more cunning than that of the plant.<sup>1</sup> *Fats, weight for weight, have over twice as much heat-giving power as carbohydrates; nine calories per gram as compared with four. Where does this energy come from? From the unoxidized carbon and hydrogen of the fat molecule, of course. For though fats are made of the same elements as carbohydrates, — namely, carbon, hydrogen, and oxygen, — the relative amount of oxygen is much smaller, so that the carbon and hydrogen atoms can take up more oxygen and hence provide more energy than can the carbohydrate molecule.*

<sup>1</sup> It must not be supposed that plants have no fats or that animals have no carbohydrates. Some plants have large amounts of fat; think of peanut butter, cocoa butter, cotton-seed oil, and olive oil. Cereals have small and nuts often large amounts of fat.

## CHEMICAL COMPOSITION OF FATS

It is worth trying to understand something of the chemical structure of fats because of the help that knowledge will give us in the study of soaps and of fat digestion.

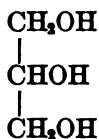
**What are Fats Composed Of?** — *Fats are combinations of fatty acids and glycerin.* When the fat molecule is split apart by strong reagents or by digestion, it breaks up into these two constituents. (An experiment showing the production of fatty acids by the splitting of fats is described in the Chapter on Digestion. See page 109.)

**There is very little Oxygen in Fatty Acids.** — Fatty acids (of which there are a great many) contain in their molecules varying numbers of carbon and hydrogen atoms, but no matter how many carbon and hydrogen atoms, only two oxygen atoms. Thus from acetic acid,  $C_2H_4O_2$ , with its two carbon atoms, to stearic acid,  $C_{18}H_{36}O_2$ , with its eighteen, they all have exactly two oxygen atoms. These are the only oxygen atoms in the fat molecule. Each fatty acid molecule has, of course (like all acids), one hydrogen atom, which is replaceable when the acid combines with a base.

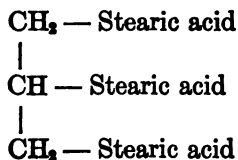
The other component of fats is *glycerin*. *Glycerin*

(Chapter VIII) is an alcohol and has three OH groups.

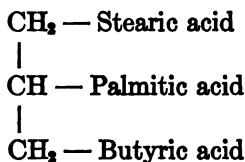
Its formula is : —



Now, alcohols act like bases ; that is to say, they combine with and neutralize acids. (For instance, the reader will remember that when sodium hydrate, NaOH, is neutralized by hydrochloric acid, HCl, the sodium atom separates from the OH group and joins the acid, displacing, of course, the H from the acid molecule. The same thing happens when glycerin and fatty acids combine and neutralize each other.) The OH groups separate from the glycerin to be replaced by fatty acid molecules. And as there are three OH groups to the glycerin molecule, each one of them in turn can be replaced by a fatty acid : all three of the OH group may be replaced by the same fatty acid or they may be replaced by different fatty acids. Thus one might get a fat whose structure would look like this : —



or one whose structure would look like this :—



As there are a great many different fatty acids to choose from, there is a possibility of a great many different fats.

The fats of no two animals or plants are the same in composition. The different flavors of various kinds are due to the different fatty acids. Likewise the exact temperature at which each fat melts or solidifies is constant and characteristic. For all fats can be obtained solid or fluid, according to the temperature. Those which are fluid at ordinary room temperatures (olive oil, for example) can be solidified at lower temperatures.

#### PHYSICAL PECULIARITIES OF FATS

A little knowledge of some of the physical peculiarities of fats illuminates a number of common domestic phenomena. Fat readily soaks into many substances and changes their light-transmitting property so as to cause *grease spots*. A drop of fat on a piece of paper makes a spot which is translucent when



held to the light. This effect on paper offers a convenient *test* to determine whether any substance contains fat.

**Solubility.** — Fat is *not soluble in water*, but is somewhat soluble in alcohol and extremely *soluble in ether*. Test this by pouring a drop or two of olive oil into tubes of water, alcohol, and ether, and shaking well. On standing, all the oil quickly collects in droplets at the top of the water; some of it is dissolved in the alcohol, and all of it disappears in the ether.<sup>1</sup> Ether and such commercial products as naphtha, benzine, and gasoline *owe their cleansing power entirely to their ability to dissolve fats*.

**Emulsions.** — When fat is mixed in certain kinds of fluids it neither dissolves nor collects again as large globules. Instead it *divides automatically into smaller and smaller globules*, until the droplets become microscopic in size and remain uniformly suspended throughout the fluid. Such mixtures are opaque and are called emulsions. Milk is a good example of an emulsion.

In order that an emulsion can be formed, there must be some substance in the solution which forms

<sup>1</sup> Remember the inflammable nature of ether and do not perform this experiment if there is an open flame in the same *room*.

a film on the surface of the globules of fat and prevents their running together. In milk this function of preventing the fat globules from running together is performed by proteids. In other instances soap performs this function. Dissolve a little green soap in water and shake with it a few drops of olive oil. Instead of collecting at the top, the oil remains suspended in the solution as a milky emulsion.

#### SOAPS

Ever since the time of the ancient Romans, perhaps even longer, housewives have manufactured crude soap for cleansing purposes by boiling together fat and lye (an alkaline substance dissolved from the ashes of plants). This traditional process was handed down from generation to generation, but it was not until the beginning of the nineteenth century that the underlying chemistry was discovered, so that purified soap could be made. And only in relatively recent years has it been detected that soap is formed in the intestines and plays an important rôle in the digestion of fats.

**Manufacture of Soap.** — Let us manufacture some soap ourselves. Then we will be able to understand its chemical composition. Soap is made by

*heating fat with strong alkali.* Add some olive oil <sup>1</sup> to a 30 % solution of sodium hydrate in alcohol and boil gently in a water bath. The oil gradually disappears in the solution which remains clear, and the result is an alcoholic solution of soap (like tincture of green soap). Several tests can be applied to show that this is soap and not merely dissolved fat. Thus a little of it poured into water forms *a smoky solution* which on shaking *lathers*. No oil globules are seen in the water.

The alkali is used up in this process of making soap. If we were to keep on adding olive oil until no more would disappear in the solution, we would find that the sodium hydrate had been almost completely neutralized.

Now what neutralized the alkali? Evidently the fatty acids present in the fats. So what the sodium hydrate actually did was to split the fat into its constituent fatty acids and glycerin, and then to neutralize the fatty acids.<sup>2</sup> So *soaps are compounds (really salts, see Chapter VII) of sodium or potassium with fatty acids, just as fats are compounds of glycerin*

<sup>1</sup> One of the finest kinds of soap, Castile soap, is made from olive oil, and has been so made for centuries.

<sup>2</sup> Glycerin, of course, is set free in this exchange, and this is the regular process of manufacturing glycerin; it is a by-product of soap making.

*with fatty acids.* Thus our ordinary hard soap consists of sodium salts, and soft soap of potassium, salts of fatty acids.

**Solubility of Soaps.** — Soaps have very characteristic properties, a knowledge of which is of some practical interest. Sodium and potassium soaps are *soluble in water* and form rather smoky-looking solutions which on shaking give a typical foamy lather. They are *soluble in alcohol* (for instance, tincture of green soap), *but, unlike fats, not in ether.*<sup>1</sup>

**Why Salt Water is not good for Washing.** — Soap, however, is not soluble in salt water; in fact, *salt precipitates it.* This can be demonstrated by dissolving some tincture of green soap in water and adding to it some strong salt water (made by dissolving a few grams of table salt in a test tube of water). A dense white precipitate is formed at once. This process is known as “salting out” and is used in manufacturing in order to free soap of impurities. The same “salting out” is what prevents us from washing our hair with soap in the

<sup>1</sup> This is the reason that in “scrubbing up” the skin for operations with soap, alcohol, and ether, the three ought always be used in the order named. The alcohol removes any soap not washed away by water. The ether removes the alcohol and any trace of grease not removed by the soap. What ether is left on the skin disappears by evaporation.

ocean. The greasy lumps which form in the hair are precipitated soap.

“**Hard**” **Water**. — Not every soap is soluble in water; calcium soap, formed by the union of the metal calcium with fatty acids, is insoluble. Moreover, calcium has a great affinity for fatty acids, so that whenever calcium in solution comes into contact either with fatty acid or with ordinary soap the insoluble calcium soaps are formed at once. Thus pour some limewater into soap water. A curdy white precipitate is formed at once. The reason that so-called “*hard water*” which occurs in certain parts of the country is not suitable for washing purposes is that it contains small amounts of calcium salts dissolved from rocks in the ground.<sup>1</sup>

**How Soap Cleanses**. — Soaps emulsify fats. *The cleansing property of soap is largely due to this power of emulsifying the fat and grease which collect on the surface of the skin and of the objects we handle; by emulsifying this film of fat the soap removes with it the particles of dust and the germs that are sticking in the fat.*<sup>2</sup>

<sup>1</sup> See McIsaacs, “Hygiene for Nurses.”

<sup>2</sup> The greasy scum left in the bathtub is due to the fact that the large amount of water dilutes the soap until it is no longer able to hold all the fat in emulsion.

The important points to remember in this chapter are that neutral fats are compounds of fatty acids and inorganic bases, that alkalies make soaps from fats, and that soaps in turn emulsify fats. Understanding this will help greatly to understand the splitting apart of fats that occurs in the process of digestion to be discussed in a later chapter.

## CHAPTER XI

### PROTEIDS

As the chemists made one successful attack after another on various kinds of organic substances, as they unraveled the complicated structures of carbohydrates, of alkaloids, as they made synthetically all sorts of compounds from indigo to rubber, there always remained one class of substances that contained nitrogen and that defied their keenest efforts. And strangely enough these substances seemed to be the most important of all. They were *found in every living cell*; they turned out to be absolutely *indispensable in the food of every animal*. In fact, so fundamental were these substances that they were often referred to as living matter par excellence, as the physical basis of life. And yet until a few years ago we had no conception of their chemical structure at all.

To-day this is changed. The proteids are still far from an open book. The exact structures of only a few of the simplest ones are known. Their

synthesis has been little more than begun. Yet the general plan of the proteid molecule is no longer a mystery.

**Elementary Composition.** — It is true that the early chemists, from the time of Liebig and Wöhler on, knew the elements of which proteids were compounded, — *carbon, hydrogen, oxygen, and nitrogen* (and sometimes in addition *sulphur, phosphorus, and iron*). They were even able to find out with considerable accuracy how much of each of these elements was present in a given proteid. <sup>23</sup> But there they had to stop. The proteid molecule was of such enormous size (containing not merely dozens but hundreds and sometimes even thousands of atoms) and of so great complexity that analysis seemed impossible.

**Structure.** — The solution of the mystery has come from a careful study of the products of the digestion of proteids, and from imitation of this digestion by the splitting up of the proteid molecule with strong acids. By these methods it was found that the *proteid molecules are vast congeries of linked-together amino acids*.

What are amino acids? They turn out to be our old friends the *fatty acids*, into the molecule of each of which a new *nitrogen-containing atom group*,



NH<sub>2</sub> (known as amine and resembling in some ways ammonia, NH<sub>3</sub>), has been inserted.

Not that proteids are composed exclusively of these. There are other atom groups, such as, for instance, aromatic groups (the closed rings of carbon atoms referred to in the Chapter on Organic Chemistry ; see page 62).

**Classes of Proteids.** — But before we get too deeply involved in their chemical structure let us get acquainted a little more closely with some of the proteids themselves. *The number of different proteids is almost unlimited.* Each animal or plant possesses at least several proteids, and it is likely that no two proteids in separate species of animals or plants are identical. This is readily understood when we think of the complexity of the proteid molecule and remember that the shifting in position of a few atoms makes a new substance. We will discuss three principal classes of proteids, the simple proteids, the compound proteids, and the albuminoids.

**Simple Proteids.** — The most important proteids are the so-called native, *or typical, or simple*<sup>1</sup> *proteids* such as the *albumins* and *globulins* found in egg

<sup>1</sup> The term "simple," though often used, is really poor because these are actually among the most complex of all proteids and have molecules of very great size.

white, in blood serum and in milk whey, the *gluten* and *legumen* of plants, the *myosin* or muscle proteid, and the *fibrinogen* of blood plasma (from which is derived the fibrin, — the tough part of a blood clot).

**Compound Proteids.** — Of equal rank with these are the *compound proteids* from the molecules of which some special non-proteid group can be split off. Thus *hæmoglobin*, the important red coloring matter of the blood cells, is composed of an iron-containing fraction combined with proteid; the *caseinogen* of milk (from which, on coagulation, comes the casein, curd, cheese) is a compound of phosphoric acid and proteid; *mucin*, found in mucus, is a compound of sugar with proteid.

**Albuminoids.** — *All the above proteids are very soluble* and when taken as food are *easily digested* and assimilated. There are other proteids (called *albuminoids*) which form the connective and protecting tissues of the body; they are more or less *insoluble* and are of relatively little value in nutrition. Among these are collagen (the basis of connective tissue and tendons, from which by prolonged boiling we obtain *gelatin*), and keratin, the proteid of skin, hair, and nails. *Keratin* contains much sulphur, and it is the oxidized sulphur which gives the disgusting smell to burnt hair or skin.

Now that we have an idea of what the proteids are and where they are to be found, let us consider some of their properties.

#### SOLUBILITY

Proteids (except the albuminoids) are very soluble in salt water and also (except the globulins) in plain water. Their solutions are *opalescent* and are very *viscid* and sticky, so that even very dilute solutions (as dilute as one part of proteid in one thousand of water) will form a more or less permanent *foam* when shaken. As found in living cells proteids are always dissolved or, at least, combined with much water.

#### COAGULATION

Every one knows the change in appearance of meat or eggs after *cooking*. This hardening is an instance of an alteration produced by heat in almost all proteids,<sup>1</sup> and known as coagulation. Superficially it has a certain resemblance to precipitation of a solid from a solution. But coagulation differs from precipitation in this regard: it is not reversible, *it is permanent*; a proteid once coagulated is unalterably changed; nothing can restore it to its former state. And

<sup>1</sup> Gelatin, certain vegetable proteids, and the partly digested proteids (proteose and peptone mentioned below) are exceptions.

living cells whose proteids are coagulated are inevitably killed.

This is the reason for the *sterilizing effect of heat*. The remarkable resistance of the spores of certain bacteria to heat sterilization<sup>1</sup> will at once occur to the reader. Can this be explained? If all living cells contain proteids, why are not the proteids of the spores coagulated by steam and the spores at once killed? Proteids as they ordinarily occur contain water; but when thoroughly dried they are coagulated only by extreme degrees of heat. In spores the proteids are condensed so as to be almost free of water. The resistance of dried proteid to coagulation explains also the well-known superiority of moist heat (steam) to equal degrees of dry heat in sterilization.

**Coagulation Test for Albumen.** — Heat coagulation affords a very delicate way of testing for any coagulable proteid, even in small traces. Thus if a drop of blood serum is mixed in a test tube of water and the test tube, held by the bottom, is brought to a flame so that the upper layer of fluid boils, a cloud forms in the upper part. On addition of a drop of dilute acid the cloud becomes much denser, because a slightly acid reaction aids in the coagulation of

<sup>1</sup> See McIsaacs, "Bacteriology for Nurses."

proteids. This method is used to detect traces of albumin in urine.

**Coagulating Effect of Salts of the Heavy Metals. —** Coagulation can be brought about not only by heat, but by many *chemical agencies*.<sup>1</sup> Thus if to a test tube containing egg white or blood serum is added a solution of *bichloride of mercury* or of *silver nitrate*, a dense coagulum is precipitated at once. These and many similar substances owe their disinfecting power as well as their local poisonous properties to their coagulating effect on proteids.<sup>2</sup> Their mode of action, however, betrays their limitations as disinfectants, because in coagulating proteid they combine with it and hence are unable to penetrate deeply or to disinfect matter containing much proteid.

#### TESTS FOR PROTEID

There are many useful tests. The coagulation test is often applied. For proteids in general the

<sup>1</sup> The term "coagulation" is also unfortunately applied to the clotting of blood and milk. These processes are different from ordinary coagulation and are really due to the formation of special new proteids, — fibrin from the fluid fibrinogen of plasma, casein from the fluid caseinogen of milk.

<sup>2</sup> By no means all the things which precipitate proteids coagulate them. Thus alcohol (if applied for a short time), or concentrated salt solutions, precipitate without coagulating. Such precipitated proteids can be redissolved.

*nitric acid test* is very convenient. Probably the reader has already, in handling nitric acid, unconsciously applied this test to the skin of fingers. Nitric acid, though colorless, stains the skin a deep yellow. If the very natural attempt is made to neutralize the acid by applying some alkali, such as ammonia, the stain instead of disappearing becomes of an intense orange color. (Add a little strong nitric acid to some egg albumin. The acid first precipitates the albumin, then dissolves it, and turns it yellow. On addition of an excess of ammonia the color deepens and becomes a beautiful orange.)

#### THE FUNCTIONS OF PROTEIDS

It has already been stated that proteids are indispensable in the diet of animals. The amount of proteid actually needed may be exceedingly small, but *sooner or later every animal must receive proteids* to replace the burnt-up or destroyed proteids in its own tissues, — otherwise it will die. An animal can do without fats provided it gets enough carbohydrates to supply it with energy, or without carbohydrates provided it gets enough fats. But it is *constantly using up its own proteid* in bringing about the various chemical processes of life and the used-up proteid must be replaced.

**Where do Animals get their Proteid? —** The *proteids in animals are all ultimately derived from plants*. In the case of the herbivorous or plant-eating animals, the proteids are derived directly by the process of digestion from plants. The carnivorous or flesh-eating animals get their proteids second-hand, so to speak, from the flesh of the plant-eating animals. The *plants in turn manufacture their proteid from inorganic nitrogen compounds* (ammonia, nitrites, and nitrates) in the soil. An animal could die of "nitrogen starvation" in spite of breathing the pure nitrogen which forms 70% of the air,<sup>1</sup> if it were not supplied with proteid directly or indirectly by plants.

Why are proteids so indispensable? We do not know enough about the chemistry of the cell as yet to give a complete answer to this question. For some reason the cell must constantly destroy its own proteid in order to maintain life. The proteids have been compared to the kindlings of a fire, of which carbohydrates and fats are the staple fuel.

<sup>1</sup> Plants also are unable to utilize the nitrogen of the air. The only way in nature, so far as we know, by which the inert nitrogen of the air is converted into the forms in which plants can utilize it, is by the action of certain bacteria which grow in the soil. So ultimately all other animal and vegetable life is dependent on these *nitrifying bacteria* of the soil.

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Not every nitrogen-containing substance in the body or in the food is proteid. There are many other nitrogenous compounds, — mostly derived from proteids. *Meat extract*, for instance, — bouillon, beef tea, — consists of such nitrogenous but non-proteid substances which although practically devoid of nutrition are nevertheless of great value in diet because of their flavor and their stimulating effect on digestion.

#### PARTLY DIGESTED PROTEIDS (PROTEOSES AND PEPTONES)

The proteids we have discussed thus far occur as part of the living organism. When, either as the result of digestion or of the action of strong acids or alkalies, the proteid molecule is broken up, the first *large fragments* that result are the molecules of substances known as *proteoses*. When these are a little further disintegrated the result is *peptones*. Proteose molecules contain a large number of amino acids, peptone molecules a smaller but still considerable number. *Proteoses and peptones are still proteids and give all the proteid tests. However, they cannot be coagulated.* (This can be demonstrated by dissolving in water some powdered meat peptone, derived from the artificial digestion of meat and really



containing proteoses as well as peptones. On boiling and adding dilute acetic acid to this, absolutely no trace of coagulation is seen.) When peptone molecules are further broken up the resulting substances are no longer proteids, but amino acids or small groups of amino acids called polypeptids.

Proteoses and peptones have not the bland or pleasant taste of other proteids, but taste *very bitter* (whence the bitter taste of peptonized foods).

## CHAPTER XII

### DIGESTION

OUR bodies are built up chiefly of proteids, fats, carbohydrates, and inorganic substances: so is our food. But the particular proteids, fats, carbohydrates, and inorganic substances in our food are entirely different from those in our body. The process by which those in our food become chemically changed into those in our body is the process of digestion. It is purely a chemical process.

**What brings about the Chemical Changes in the Body?** — During digestion very profound changes are brought about in the food materials. These are brought about by the action of certain substances known as *enzymes*, which are produced in the mouth, stomach, and intestines. The enzymes (formerly called ferments or unorganized ferments) are very wonderful substances. *Each enzyme is able to work on one particular kind of substance, — and no other.* On this account an enzyme has been compared to a key which will fit one particular lock, — that is, will unlock one particular kind of molecule. Ex-

zymes do the work which otherwise can only be done by very powerful chemical processes, such as strong acids or alkalis, considerable heat, and similar means. Yet enzymes themselves are present, even when they produce great effects, only in small traces and they are almost inert and inactive chemically against anything excepting the particular kind of substance that they can digest. Thus, to carry the illustration a little farther: if enzymes correspond to keys which will unlock only particular doors, the ordinary chemical process might be compared to battering rams which will break through any door.

**Chemical Nature of Enzymes.** — The exact chemical composition of enzymes is not known, but they are almost certainly *proteid*. *All of them can be destroyed or killed by boiling, and in general by all of the same things as coagulate proteids.* Each enzyme has certain particular set conditions which it must have in order to work. Thus most of our digestive enzymes work best at body temperature. Some enzymes will work only if in slightly alkaline solution; others only if the solution is acid; some can work in either acid or alkaline solution.

**All Cells contain Enzymes.** — We will discuss only the most important enzymes that are found in the human digestive tract, but the student ought

to know that there are really very many more enzymes than these. Every living cell contains enzymes and, in fact, brings about most of the chemical changes which are necessary for its life, by means of enzymes. Furthermore, *the action of enzymes is not only to break down substances into simpler forms, as occurs in our digestive tract, but also to build up simpler substances into the more complicated ones needed by the body.*

#### SALIVA

The saliva is the first digestive juice which the food meets. It contains one important enzyme, — *ptyalin or amylase*. (The new system of naming enzymes uses the ending “ase” to a word to indicate enzyme, and attaches the ending to the name of the substance that the enzyme works on: thus, *amylum* (starch), *amylase*.) *Ptyalin breaks starch down* to dextrin, then to maltose, and then, finally, to *glucose*, or simple sugar.<sup>1</sup>

In the Chapter on Carbohydrates it was stated that boiling with a strong acid would reduce starch to dextrose. Saliva will do the same thing and more

<sup>1</sup> The action of diastase or malt extract (the vegetable enzyme of germinating barley) on starch is closely similar, but does not proceed quite so far.

quickly, and without boiling. This can be proved by a very simple experiment. Take a test tube full of saliva obtained simply by chewing on a piece of paper. Filter the saliva to make it clear. Take a test tube of starch paste and first apply to the starch two tests to prove that it is starch and is free from any simple sugar. The addition of a drop of iodine turns it a deep blackish blue. Boiling a drop or two of the starch paste with Fehling's solution gives no reduction of copper (no yellow precipitate). Now mix some saliva and starch paste in a test tube and put the test tube in a water bath at body temperature for only a few minutes. Then test the contents of the test tube again with iodine, and you will see instead of the deep blue color a brownish color indicating that there is dextrin present. Add a few drops to Fehling's solution and boil, and you see an abundant yellow precipitate, — an indication that some of the starch has been broken down beyond the dextrin stage to dextrose (grape sugar) by the action of ptyalin.

**What Effect has Boiling on Enzymes?** — Now repeat the experiment; only instead of using the fresh saliva use some *saliva which is first boiled* and you will see that *nothing happens*. The starch remains quite unchanged. The boiling kills the enzymes.

**Effect of Acids on Starch Digestion.** — Saliva, as one can see by the bluish color which it gives to litmus paper, is weakly alkaline in reaction. Ptyalin works best in an alkaline or neutral fluid. *An acid reaction not only stops its action, but quickly destroys it.* If one adds a little hydrochloric acid to saliva, lets it stand a few minutes, and again tests its effect on starch, one can see that it has absolutely no digestive power. The acid kills the enzyme quite as effectually as boiling does.

#### GASTRIC DIGESTION

The next digestive secretion is the gastric juice. It is strongly acid in reaction due to the presence of *hydrochloric acid* in the strength of about 0.2%. Gastric juice contains *two important enzymes*,—*rennin and pepsin*. Rennin has the power of coagulating the caseinogen of milk. The coagulation of milk is the preliminary stage to its digestion. Artificial gastric juice, prepared by making an extract of the stomach of the pig, is sold commercially as pepsin and is used medicinally. This pepsin dissolved in water and added to milk, which is then allowed to stand at body temperature for a few minutes, promptly curdles the milk.

**Rennin.** — Rennin is very difficult to separate from pepsin. That is the reason that we use the substance called pepsin, which is really not pure pepsin, but an extract of stomach glands containing both pepsin and rennin, for coagulating milk. After the milk has coagulated, the fluid part which separates out is *whey*. If whey is heated at once, the pepsin does not have time to produce much peptone or proteose. But if it is allowed to stand, the proteoses and peptones which form give it a bitter taste. The fat in the milk for the most part remains tangled in the mesh of the coagulated casein. Rennin works either in an acid or a neutral medium.

**Pepsin.** — Pepsin is the stomach enzyme which digests proteids. It dissolves them and breaks them down partly or entirely to proteoses and peptones. *It is active only in the presence of acid and it is destroyed if the reaction becomes alkaline.*

The effect of pepsin on little pieces of coagulated egg white and on little shreds of washed blood fibrin can easily be studied. Prepare the fibrin first by washing a piece of blood clot obtained at the slaughterhouse in running water until all the red blood cells are washed out. From the yellow fibrous clot that is left tear off five little shreds and put them in test tubes. In other test tubes put five little cubes of

boiled egg white. Prepare the pepsin solution by dissolving a few grains of powdered or scaled commercial pepsin in a few cubic centimeters of 0.2% hydrochloric acid. Add some of this to a tube containing fibrin, and some to a tube containing egg white. Boil a little of the pepsin solution and add it to a second pair of tubes with egg white and fibrin. Neutralize another portion with sodium hydrate and add it to a third pair of tubes of egg white and fibrin. To a fourth set of tubes add some strong alcohol and then the pepsin solution. In a fifth pair of fibrin and egg white tubes put hydrochloric acid without pepsin. Put all the tubes in a water bath at body temperature for an hour. At the end of that time, in the tube containing pepsin and hydrochloric acid alone, the egg white and the fibrin will have become digested, whereas in the tubes containing boiled pepsin, alkaline pepsin solution, alcohol with pepsin, and hydrochloric acid alone, digestion will not have occurred, — the egg white and fibrin will still be there. In the two tubes, the contents of which are undergoing digestion, at the end of fifteen or twenty minutes both the egg white and the fibrin will look rather swollen and semi-transparent and be apparently fading away at the edges. At the end of three quarters of an hour the



fibrin will have almost entirely crumbled away and disappeared. The egg white too will be almost entirely gone, but a little piece of it may still be left.

By boiling and filtering the fluid (to remove any coagulable proteid) and then with the clear filtrate doing the nitric acid test for proteid, it is easy to prove that in this solution are *proteoses and peptones*.

#### PANCREATIC DIGESTION

When the stomach contents are poured into the intestine they meet at once the *pancreatic juice and bile*, both of which are *alkaline* in reaction. The alkalinity at once stops the further action of the pepsin, but not the further digestion of proteids, as we will see.

The **pancreatic juice** is the most important digestive secretion in the body, and is emptied into the duodenum along with the bile. It contains at least *three very important enzymes*.

The first of these is *amylase*, a starch-digesting enzyme which seems to be identical in action with ptyalin. Its effect on starch is exactly the same as that of saliva.

**Trypsin.** How it differs from Pepsin. — The second important enzyme is a proteid-digesting enzyme known as *trypsin*. It attacks the same

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proteids as does pepsin, but it only acts in an alkaline medium and it digests the proteid much farther than pepsin; namely, it not only reduces the typical proteids to the stage of proteoses and peptones, but, also, if the digestion is continued long enough, to the much simpler stage of *polypeptids and even amino acids*. It is easy to demonstrate the effects of trypsin by dissolving some commercial pancreatin in a weak alkaline solution, namely, 0.4% sodium carbonate solution, and adding some of this solution to little pieces of fibrin and egg white. When these stand for three quarters of an hour at body temperature the effect on the particles of proteid is very similar to the effect of pepsin in hydrochloric acid.

**What digests Fats?** — The third important digestive enzyme in the pancreatic juice is a fat-digesting enzyme known as *lipase*. This has the power of splitting up fats into their constituent fatty acids and glycerin. In the Chapter on Fats I showed that fats can be split up by boiling with powerful acids or alkalies. The feebly alkaline pancreatic juice does exactly the same thing. This can be conveniently demonstrated by an experiment with the fat of milk.

**An Experiment to show the Splitting of Fat by Pancreatic Lipase.** — Take a large test tube of milk and to it add a little litmus solution as an indicator

as to whether the milk is acid or alkaline. Usually the color is pinkish, indicating that the milk is slightly acid. Make it slightly alkaline by adding a little weak sodium carbonate solution. The color is now bluish. Now divide the milk in two small test tubes: to one test tube add a little of the artificial pancreatic juice, made by dissolving pancreatin in sodium carbonate solution. The color of the two tubes will still be exactly the same, or, if it is not, make it so by adding a little sodium carbonate solution to one or the other. Now put both tubes in the water bath. After a short while take them out and the tube to which pancreatic juice was added will now have turned bright pink. *The fatty acids of milk fat will have been split off from the glycerin* and, being acids, will have turned the litmus solution red. This same thing happens in the intestines; but in the intestines there is always an excess of alkali present, both from the pancreatic juice and from the bile, so that the fatty acids do not turn the reaction actually acid, but are neutralized to form soaps.

**Of What Use is Bile?** — *The bile secreted by the liver contains no enzymes*, but is nevertheless extremely important for fat digestion, as it keeps the contents of the intestines alkaline and thus *aids in*

*the emulsification of fats*, which is essential to their absorption. In neutralizing the fatty acids, of course, it forms soaps from them.<sup>1</sup>

#### INTESTINAL SECRETION

**Erepsin.** — The secretion of the glands in the intestinal wall also contains a number of enzymes. There are special enzymes for a number of functions: for instance, enzymes for breaking down the disaccharides, like cane sugar and milk sugar, into simple sugars; *but the most important enzyme contained in the intestinal juice is a proteid-digesting enzyme known as erepsin.* Erepsin does not digest the typical proteids at all, but only attacks peptones (which have been produced by the action of pepsin and trypsin) and breaks the peptone down to amino acids.

#### WHY DIGESTION IS NECESSARY

Now let us stop for a moment and consider *what is the purpose of all this chemical decomposition* of food products before absorption. Our bodies are built up of carbohydrates, fats, and proteids. So is our food. Why can we not simply absorb the pro-

<sup>1</sup> Absence of bile causes the fatty stools of jaundice patients. See Chapter XIV, page 134.

teid, fat, or carbohydrate from the food and use it in our bodies? Each species of animal has its own particular kind of proteid, or fat, or carbohydrate. Thus, though human muscle may be built up by the eating of beef muscle, of chicken muscle, of fish muscle, it is entirely different in its nature from any of these. The muscle of the Chinaman who eats nothing but fish differs in no way from the muscle of the Englishman who eats nothing but beef, and the reason is now perfectly clear. *The body breaks down all the proteid* that is offered to it, — whether in the form of muscle, grain, milk, or any other form, — to the simplest building stones of proteid, namely, the amino acids. *It then from the mixture selects those particular amino acids which it needs* to build up its own kind of muscle proteid (or blood proteid, or other cell proteid) and rejects or burns up all the other amino acids. It does the same thing to all the fat and carbohydrate it gets, — disintegrates and then reconstructs them to suit its own needs.

## CHAPTER XIII

### URINE

**Functions of Kidneys.** — The chemistry of urine is of great practical importance, as the kidneys are the chief excretory organs. The principal function of the kidneys is to *rid the body of waste products derived from the burning up of nitrogenous compounds*. Besides this the kidneys have to *keep the amount of salt in the body adjusted* to exactly the right point by excreting all superfluous salt taken in with the food, and they help the body get rid of various poisonous substances whether manufactured by the body itself or absorbed from the intestines or elsewhere.

**How are Oxidized Carbon and Hydrogen Excreted?** — In discussing the combustion of body substances in Chapter IV it was shown that the combustion of organic substances always produce some water and some carbon dioxide. The carbon dioxide is excreted almost entirely by the lungs. Some of the water is excreted by the lungs, some by the skin, and some by the kidneys.

**How is Used-up Nitrogen Excreted?** — When *nitrogenous substances*, particularly proteids, are *oxidized* in the body the products of combustion of the nitrogen are excreted chiefly by the kidneys, in the form of several different substances. The substance which contains about three quarters of the burnt-up nitrogen is known as *urea*. By measuring the amount of urea excreted in twenty-four hours doctors can get an idea as to whether the kidneys are able to excrete nitrogenous waste sufficiently. The most important of the other substances representing the rest of the burnt-up nitrogen is known as *uric acid*; it is believed to be produced from the oxidation of proteids in the nuclei of the body cells. *Uric acid* is a normal constituent of urine, although there is a mistaken popular impression that its presence in the urine means gout.

**How Salt Balance is Maintained.** — Next to nitrogenous constituents the most important substances in the urine are the *salts*. Practically all of *our food contains more or less salt* and we are thus constantly taking into our bodies various amounts of different kinds of salts. It is the function of the kidneys to maintain the proper concentration of the proper salts in the body by excreting all that is *unnecessary*.

**Purpose of Urine Examination.** — The object of urine examination is to determine (1) whether the kidneys are performing their function properly, (2) whether there is disease at any point in the urinary tract, (3) whether there is any substance indicative of disease of any other organ. There are hundreds of different tests done on urine for special purposes. Only those will be discussed which are of great practical importance and which the nurse should know the significance of.

A routine urine examination includes the following most important points:—

- (1) Amount in twenty-four hours
- (2) Color
- (3) Transparency
- (4) Odor
- (5) Specific gravity
- (6) Reaction (whether acid or alkaline)
- (7) Albumin
- (8) Sugar
- (9) Microscopic examination

#### (1) THE AMOUNT

The *amount* of urine passed in twenty-four hours by an adult or child above eight years is on the average from 1000 to 2000 cubic centimeters. It represents about 60 or 70% of the water taken in.



**Measuring Urine.** — In measuring the amount it is necessary to start with the bladder empty, — that is to say, the patient should void just before the hour at which the twenty-four-hour specimen is to be commenced, and the patient must, of course, empty the bladder again just before the end of the twenty-four-hour period, so that the actual amount formed by the kidneys in twenty-four hours is obtained. The urine is best collected in a 2-quart bottle or jar, kept in a cool place, and often some preservative is added (a few cubic centimeters of chloroform or toluol or a few crystals of thymol).

**Normal Variations in Amount.** — The amount of urine varies greatly even in health. It is *diminished* in warm weather and in fact by anything which causes much perspiration. It is *increased* by drinking copiously and by anything which decreases the amount of perspiration.

**Pathological Variations in Amount.** — The observation of the amount is of importance in many diseases. The quantity is *diminished* in all fevers (due largely to the much greater evaporation from the skin in fevers), in acute nephritis (acute Bright's disease), in the final stage of chronic nephritis, and in heart failure. It is also diminished in all diseases in which a large amount of water is lost through some

other part of the body, as in diarrhea and dysentery, in hemorrhage, and in vomiting.

*Suppression* of the urine (or failure of the kidneys to secrete any urine) occurs in very acute forms of nephritis, — such as nephritis caused by certain poisons like mercury and carbolic acid. It may also occur from the obstruction of the ureter, or occasionally as a reflex nervous result of operation, injury, or disease of some part of the urinary tract.

*Retention* of urine means failure of the bladder to empty out the urine which has been secreted by the kidneys. It is of importance practically to distinguish between retention and suppression. Retention is due to a great variety of different causes, such as paralysis of the bladder, obstructions of the urethra by tumors, by a large prostate gland, by urinary stones, etc.

Careful measuring of the amount of urine by the nurse is a thing of the greatest possible importance in all forms of kidney disease and in all such diseases (for instance, scarlet fever) as are likely to be complicated by kidney disease. In such cases the increase in the amount of urine generally means that the patient is improving or that the treatment is effective. It is always desirable to measure the

*amount of fluids taken by the patient* so that it can be compared with the amount of urine excreted.

The amount of urine is *increased* (this is called *polyuria*) chiefly in three diseases: (1) in diabetes mellitus (the ordinary form of diabetes in which sugar is found in the urine), (2) in diabetes insipidus (the disease whose principal symptom is an excretion of large amounts of urine), (3) in chronic Bright's disease.

## (2) COLOR

The color of normal urine varies greatly. It depends largely on the amount of urine excreted. It varies from pale straw color in persons who are passing a great deal of urine to lemon yellow and to deep amber color in persons who are passing a small amount of urine. High-colored urine occurs particularly in fevers. Abnormal colors are caused by a number of different things. The color of fresh blood is easily recognized. Very small amounts of blood give a *smoky appearance* without actual red color. The *yellowish green* color given to urine by *bile* in cases of jaundice is characteristic. It is important to be able to recognize this color, as there are cases of liver disease in which the amount of bile retained by the body is too small to cause noticeable

jaundice in the skin, but in which bile nevertheless is found in the urine. There are a number of chemical tests employed by doctors to detect these small traces of bile. Urine which contains bile stains paper or linen a peculiar yellow, and if a little of it is shaken up in a test tube, a foam forms on the top which is a yellow color,—whereas the foam of normal urine is white. Urine may be colored reddish after the taking of certain drugs such as rhubarb, senna, santonin ; or colored blackish in carbolic acid poisoning, or green after the use of methylene blue as a drug.

### (3) TRANSPARENCY

**Significance of Turbid Urine.** — Normal urine is perfectly clear, with a very faint cloud of mucus which collects if the urine is allowed to stand for a couple of hours. The turbidity of urine is an important thing for the nurse to notice. *The turbidity which is present when the urine is passed is the only kind that is of any practical importance.*

**Turbidity which occurs in urine which has been standing** for any length of time may be due to growth of bacteria in the urine or to the formation of various kinds of deposit, such as deposits of *phosphates* or substances known as *urates*. This latter urate deposit is likely to be brick dust in color and is very

common in urine which has been left *standing in the cold*, — so common, in fact, that it has been very widely used in fraudulent advertisements to frighten healthy people into thinking that they had kidney trouble and taking some patent medicine. *It is never a sign of disease.* It is easily recognized by the fact that it *dissolves if the urine is warmed.*

The turbidity which is due to the growth of bacteria is accompanied by the development of an ammoniacal smell and is a disturbing factor in making several of the special tests on urine. For this reason when urine cannot be sent to the laboratory at once or when twenty-four hour specimens are collected, the urine should be kept in the cold (ice box) or some harmless preservative should be added, such as chloroform, thymol crystals, or toluol. As some of these substances may have an effect on certain chemical tests, it should always be noted which one has been added.

In *urine which has become alkaline* on standing there may be a heavy deposit of phosphates or of carbonates. This, unlike the deposit of urates, does not disappear on warming, but does dissolve if acetic acid is added.

**Turbidity of Fresh Urine.** — Urine which is *turbid when passed* may be so from the presence of *pus*

or of phosphates or carbonates. This occurs especially in cystitis (inflammation of the bladder), pyelitis (inflammation of the pelvis of the kidney), and various kidney inflammations (such as abscess or tuberculosis), or the turbidity may be due to pus from leucorrhea or gonorrhea. Pus settles to the bottom in an hour or two as a thick creamy layer. It can only be identified with certainty by a microscopic examination.

It is especially important to *watch for any slight turbidity* of the urine in cases in which a cystitis is likely to develop, for instance, in cases which are being *catheterized frequently*. The important turbidity of course is due to pus. Turbidity which clears up promptly on warming the urine over a flame (in the case of urates), or on adding a little dilute acetic acid (phosphates and carbonates) is never due to pus.

#### (4) ODOR

The odor of freshly passed urine may vary from the normal, especially after eating certain articles of diet such as asparagus. Urine which is foul when passed usually comes from a case of cystitis, or if the odor is fecal, from a case of fistula connecting the bladder and rectum. On being allowed to stand for

a day or more urine becomes foul-smelling from decomposition caused by bacteria.

#### (5) REACTION

The reaction of urine is tested with litmus paper (see Chapter V). *Normal urine is usually acid*, or sometimes amphoteric; that is, turning red litmus paper blue and blue litmus paper red. Occasionally when passed after a heavy meal it is found to be slightly alkaline, due to the fact that the body is using up the acid which ordinarily is excreted in the urine to manufacture the acid needed by the stomach for digestion. This is known as the alkaline tide in the urine. Urine may also be made alkaline by the giving of alkaline drugs such as bicarbonate or citrate of soda. Aside from these instances urine which is alkaline when passed is generally urine decomposed as the result of cystitis. *Urine which has decomposed after being passed also becomes alkaline.* The alkalinity of decomposed urine is due to the production of ammonia ( $\text{NH}_3$ ) by the action of a certain bacterium,—the *micrococcus urei*, which grows on urea.

#### (6) SPECIFIC GRAVITY

**What is Meant by Specific Gravity.** — The specific gravity of urine means its density, or what is the

same thing, the weight of any volume of urine as compared with the weight of an exactly equal volume of distilled water. Suppose we have two flasks each containing 1000 c.c. of distilled water, their weight exactly the same. If in the one flask we dissolve 10 grams of salt then the water in that flask will weigh 10 grams more than that in the other flask. In other words, its specific gravity will be 1.010. Hence the figure that represents the specific gravity of urine really indicates to us the number of grams of solid substance dissolved in 1000 c.c. of urine. The specific gravity varies in health, depending always on the amount of urine secreted; so that *the figure representing the specific gravity really means very little unless we know how much urine is secreted*. If we do know, then we can judge whether the patient is excreting enough solid matter or not. The most important solid matters to be excreted are urea and salts. When the kidneys are diseased they are unable to excrete sufficient of these substances.

**Cause of Dropsy. Reason for Salt-free Diet. —**

In Chapter VII it was explained why it is very important for the body to maintain the concentration of salt in the blood at precisely a certain point. If the kidneys are unable to get rid of the surplus salt, then in order to keep the concentration of the body



fluids right, the body has to retain water also. This leads to edema or dropsy. This is the reason for salt-free diet, or salt-poor diet, in cases of kidney disease.

The *normal specific gravity* of the urine is between 1012 and 1024. The specific gravity is low in chronic Bright's disease, in diabetes insipidus, and after drinking large amounts of fluid. The specific gravity is high when the amount of urine excreted is small, as in fevers; it is high especially in diabetes in spite of the large amount of urine passed, due to the sugar dissolved in the urine.

**Method of Determining Specific Gravity.** — In practice, in order to measure the specific gravity of urine we do not weigh it, but we use a much simpler method the principle of which depends on the fact that *when anything floats in water in which salts or any other solid substances are dissolved it is buoyed up and floats higher* than it would in plain water. Thus in the Dead Sea there is so much solid matter dissolved that a person cannot sink. To measure the specific gravity a special little instrument or buoy called a *urinometer* is used. It is dropped into the urine and made to float there without touching the sides of the vessel. Its stem which projects above the surface of the urine has marks on it at different

levels and these marks are labeled 1000, 1010, 1020, 1030, and so on, and the intermediate figures are indicated by strokes. One can tell the specific gravity of the urine simply by reading off the level to which this stem sinks in the urine.

### (7) ALBUMIN

**Heat Test for Albumin.** — One of the most important things which urine is tested for is albumin. There are a great many different tests; the *heat test* is the simplest and is very delicate. The test consists of pouring some of the clear urine into a test tube and boiling the upper layer of the urine, then adding a few drops of weak acetic acid (2%) and boiling again. If there is albumin present, a very faint or heavy cloudiness (precipitate of coagulated albumin) forms on boiling and persists or becomes heavier on adding a few drops of dilute (2%) acetic acid and boiling again. *If a precipitate occurs at the first boiling but clears up again entirely on adding acetic acid, it is not albumin, but harmless phosphates or carbonates.* In case the urine is alkaline before the test is made it must first be neutralized by adding a little weak acetic acid. In case the urine is not clear before the test is done it must first be clarified by filtration.

**Significance of Albumin.** — Albumin in the urine generally means disease of some sort. The most important disease in which it occurs of course is *nephritis* (Bright's disease). In acute nephritis it occurs in large amounts, in chronic nephritis in mere traces. When the heart is weak and also in fevers there may be traces of albumin in the urine without the kidneys being necessarily diseased. During pregnancy an occasional test of the urine is of great importance on account of the danger of kidney complications. Urine which has pus in it or blood has of course also albumin. This, however, does not necessarily mean kidney disease.

#### (8) SUGAR

Sugar is found in the urine chiefly in cases of *diabetes mellitus*. In healthy people, however, small amounts of sugar may occasionally appear in the urine under special circumstances, — such as after eating an excessive amount of carbohydrates. Occasionally in pregnancy or during lactation, or particularly when lactation is suddenly ended, milk sugar is found in the urine. The sugar found in the urine in diabetes is the same which normally is present in the blood; namely, dextrose (glucose, grape sugar).

*Fehling's test* for sugar in the urine is the one usually used. The *fermentation test* is also often used. Both tests are described in Chapter IX. The fermentation test is of aid in distinguishing between dextrose and milk sugar: milk sugar is not fermented by yeast but gives reduction with Fehling's test.

**The Amount of Sugar.** — The amount of sugar in the urine is one of the most important things for the doctor to know in treating a case of diabetes; and as in these cases the amount passed by the kidneys at different hours of the day varies, *the only figure that has any meaning is the total amount of sugar lost by the body in twenty-four hours.* This in turn is only of significance when it can be *compared with the total amount of carbohydrates eaten* by the patient in the same twenty-four hours. For this reason the mere percentage of sugar in one specimen or urine really means very little. It is not necessary for nurses to learn the methods of measuring the amount of sugar.

**Acetone and Diacetic Acid.** — Besides sugar there are two other things which are always extremely important to test for in the urine of patients who have diabetes; these are acetone and diacetic acid. In diabetes death most commonly results from the so-called *acid intoxication* or diabetic coma. This comes from the accumulation of certain acids in the

body, and the presence of these acids in the blood is shown by acetone or diacetic acid appearing in the urine. These same substances may also be found in the urine during starvation or in diseases in which the nourishment of the patient is very greatly cut down. There are very few chemical tests that nurses ever are called on to perform, but the test for diacetic acid is so simple, and knowing whether it is present in a given case of diabetes from day to day is so important, that the test will be mentioned here. If to a few drops of urine containing diacetic acid an excess of ferric chloride solution is added, the fluid becomes a Bordeaux red (red wine) color. This color disappears or gets fainter if the urine is boiled. (Adding an excess of ferric chloride solution means adding more ferric chloride solution than there is urine in the tube.)

**Reason for Alkaline Medication.** — When these acids are found in the urine, as a rule alkalis are ordered as medicines (sodium bicarbonate, sodium citrate) and the diet is made much more liberal even if the amount of sugar excreted becomes greater. In such cases the doctor sometimes puts litmus paper in the hands of the nurse and instructs her to give the alkaline medication at regular intervals until the urine becomes and remains alkaline.

## (9) MICROSCOPIC EXAMINATION

Nurses are never called upon to do a microscopic examination of urine, but as such examinations are often done on the patients that they are taking care of, they should know what is meant by a few of the terms used. In a microscopic examination the most important things looked for are pus, blood cells, and casts. *Pus* is recognized by the finding of so-called pus cells, which are nothing but dead leucocytes (white blood cells). The finding of *red blood cells* in urine is of great diagnostic value especially when kidney stones are suspected. Small numbers of the blood cells are often found in urine that is not the least blood tinged. *When urine is to be examined for blood cells it must be examined fresh*, as the red cells lose their outlines and are almost impossible to recognize after the urine has been standing for a day. *Casts* in the urine always point to kidney disease. Casts are very minute cylindrical bodies molded to the shape of the inside of the fine kidney tubules in which the urine is secreted. They are composed of albumin which is coagulated or solidified in the tubules. When present in large numbers they are of very grave significance. Beside these things the urine frequently contains crystals of various kinds, and bacteria.

## CHAPTER XIV

### STOMACH CONTENTS AND FECES

#### STOMACH CONTENTS

NURSES are not expected to make chemical analyses, but as they frequently have to assist doctors in securing samples of stomach contents, and as they have to make careful notes of the appearance of vomitus, they should know something about the examination of gastric juice.

**Object of Examining Stomach Contents.** — In the examination of the stomach contents much depends on the time and circumstances under which the specimen is obtained. Ordinarily we desire to find out how the stomach behaves in a definite number of minutes after the taking of a definite kind of test meal. Frequently *we wish to find out whether the stomach is capable of emptying itself* in a certain number of hours. This is the object of the taking of the stomach contents in the early morning before any food is taken. The normal stomach should be practically empty at this time of day. If there is

much fluid in it, — especially if there are any remnants of food taken the day before, — then we know that there is some delay in the emptying of the stomach into the intestine.

**Is the Pylorus Obstructed?** — When this question is to be determined, usually some easily recognized kind of food such as raisins, cranberry or currant preserves, or a few grains of rice are given the *night before*. *The kind of food remnants recognizable in the stomach contents or vomitus should be noted by the nurse and she should report how long before the kind of food seen was taken.*

*The quantity of the stomach contents should always be accurately measured;* an abnormally large amount means either obstruction at the pylorus or an excessive secretion. After a test meal usually 50 to 100 c.c. are obtained.

**Gross Appearance.** — Other facts in the gross appearance are also worth noting: whether (after an Ewald test breakfast) the bread is chewed or not, — whether there is bile present or not, — and above all whether there is any trace of blood.

**Blood in Stomach Contents.** — *Blood in the stomach contents looks brown or black, and if there is much, it has a coffee grounds appearance due to the action of the hydrochloric acid of the stomach on the hæmo-*



globin of the blood. *Bright red streaks of blood* in the stomach contents almost always come from the mouth or throat; and they *should always be noted by the nurse*, because if they subsequently become affected by the acid and dissolved in the remainder of the stomach contents, they may deceive the doctor who makes the examination later. Blood can be tested for by chemical means and an extremely minute trace of it can be detected. Its finding is of great importance and usually points either to an ulcer or a cancer of the stomach.

**Acidity.** — Next to the finding of blood the most important practical examination of the stomach contents is the measuring of the *amount of acid*. This is measured in terms of the number of cubic centimeters of a particular strength of sodium hydrate (called decinormal sodium hydrate) which 100 c.c. of the stomach contents will neutralize. Thus a doctor's report that the acidity of the stomach contents is 60 means that 100 c.c. of the stomach contents have enough acid to neutralize 60 c.c. of this kind of alkali. The amount of acid is increased in certain kinds of stomach troubles, and especially in ulcer of the stomach. It is diminished in certain other stomach troubles, and especially in cancer. In some diseases the ordinary hydrochloric acid of the stomach is almost

absent and a different kind of acid, namely lactic acid, is found ; it is produced by the fermentation of food through the agency of bacteria. *Lactic acid gives a sour odor* which the nurse can often learn to recognize.

As the saliva is alkaline, it is of great importance not to get any saliva mixed with the stomach contents ; if any is accidentally mixed in during the obtaining of the stomach contents, one should make note of the fact ; otherwise, especially if the amount of the stomach contents is small and the amount of saliva considerable, the examination of the acidity may be entirely misleading.

#### EXAMINATION OF FECES

The examination of the feces is a thing in which the nurse is sometimes of assistance. Only one or two points need to be discussed. *The most important single thing examined for is blood ;* it has the same significance here as in the stomach contents ; namely, ulceration of some kind in the stomach or intestine. Large amounts of blood of course are easily seen. Minute traces are detected by very delicate chemical tests (benzidine reaction). As any blood taken with meat will also give a positive chemical test for blood, *the patient has to be put on a meat-free diet* for

three days before one can be sure that a positive chemical test for blood in the stool really means a little bleeding into the intestines or stomach.

**Significance of Fatty Stools.** — Aside from the observation of blood the question of whether bile is present or not is of much practical importance. In cases of jaundice when the bile does not empty into the intestines the stools are of a pale gray or slate color and of a pasty consistency. This is due not only to the absence of the pigments derived from bile in the stools but chiefly to the large amount of undigested fat. It will be remembered that bile plays an important part in aiding the digestion of fat by emulsifying it. This is the reason that patients who have obstructive jaundice have to get their nourishment largely from carbohydrates and proteids, and the amount of fat in their diet is to be restricted.

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